



HAL
open science

Early speech perception in preterm and fullterm infants

Elena Berdasco Muñoz

► **To cite this version:**

Elena Berdasco Muñoz. Early speech perception in preterm and fullterm infants. Cognitive Sciences. Université Sorbonne Paris Cité, 2017. English. NNT : 2017USPCB233 . tel-03410111

HAL Id: tel-03410111

<https://theses.hal.science/tel-03410111>

Submitted on 31 Oct 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



MEMBRE DE

USPC
Université Sorbonne
Paris Cité

Labex **EFL**

ECOLE DOCTORALE 261
« COGNITION, COMPORTEMENTS, CONDUITES HUMAINES »

La perception précoce de la parole chez les enfants prématurés et nés à terme

Early speech perception in preterm and fullterm infants

Thèse de Doctorat, Psychologie Cognitive

Elena Berdasco Muñoz

Date de soutenance : Mardi 28 Novembre, 2017

Membres du Jury :

| | | |
|----------------------|------------------------|--------------------|
| Laura Bosch | Professeur | Rapporteur |
| Sharon Peperkamp | Directeur de Recherche | Rapporteur |
| Alessandra Sansavini | Professeur | Examineur |
| Bahia Guellai | MCU | Examineur |
| Thierry Nazzi | Directeur de Recherche | Directeur de thèse |

Résumé

La perception précoce de la parole chez les enfants prématurés et nés à terme

La prématurité est un problème de santé publique mondial qui affecte aujourd'hui 1 sur 10 enfants chaque année. En France, ce phénomène a régulièrement augmenté, les prématurés représentant 7,4% des nouveaux nés français en 2010, contre 5,7% en 1995. Des recherches scientifiques ont établi que les enfants nés prématurément sont plus susceptibles de rencontrer des difficultés dans le développement langagier ainsi que dans d'autres domaines cognitifs que les enfants nés à terme. Cependant, nos connaissances sur les habilités langagières précoces des enfants prématurés restent actuellement limitées. Le premier objectif de cette thèse était donc de spécifier différentes capacités de perception de la parole pendant les deux premières années, en référence à celles d'enfants nés à terme de même âge postnatal. Son second objectif était d'étudier si le degré de prématurité module les performances langagières des enfants prématurés.

Cette thèse est organisée en trois parties expérimentales. La première a exploré la segmentation, c'est-à-dire la capacité à découper la parole en mots, qui est liée à l'acquisition du vocabulaire. Nos résultats ont établi qu'à 6 mois d'âge postnatal, les enfants prématurés ont des capacités de segmentation basiques (segmentation de mots monosyllabiques, Exp. 1), comme les enfants nés à terme de même âge postnatal (6 mois ; Nishibayashi, Goyet, & Nazzi, 2015) et maturationnel (4 mois ; Exp. 2). Toutefois, nous avons aussi trouvé des différences avec les nés à terme. Si les enfants prématurés de 6 mois segmentent des syllabes intégrées dans des mots, comme précédemment trouvé pour les enfants nés à terme, l'effet de segmentation à des directions opposées chez les deux populations, suggérant différents mécanismes de traitement (Exp. 3). En outre, à 8 mois d'âge postnatal, nos résultats ne font pas apparaître de biais consonantique dans la reconnaissance des mots segmentés, comme chez les enfants nés à terme (Exp. 4). Néanmoins, des enfants bilingues prématurés et nés à terme qui ont le français comme langue dominante sont capables de segmenter des mots monosyllabiques à l'âge de 6 mois (Exp. 5).

La deuxième partie a mesuré le comportement visuel d'enfants prématurés et nés à terme face à un visage parlant dans la langue maternelle (le français) et une langue étrangère (l'anglais). Nos résultats révèlent qu'à 8 mois, les enfants prématurés ont un comportement visuel différent de celui d'enfants nés à terme au même âge

postnatal et maturationnel. Alors que les enfants nés à terme ont un comportement visuel différent dans les deux langues, ce n'est pas le cas chez les enfants prématurés (Exp. 6). Ces comportements visuels différentiels sont les premiers éléments de caractérisation de la trajectoire développementale de la perception audiovisuelle des enfants prématurés.

La troisième partie a porté sur le développement lexical. Nos résultats montrent que les enfants prématurés reconnaissent la forme des mots familiers à 11 mois d'âge postnatal (Exp.7), comme les enfants nés à terme (Hallé & de Boysson-Bardies, 1994). Concernant la production lexicale autour de l'âge de 24 mois postnatal (Exp. 8), nos résultats révèlent que les enfants prématurés ont un vocabulaire réduit par rapport aux enfants nés à terme de même âge postnatal, mais des niveaux similaires à ceux de même âge maturationnel. Cependant, un pourcentage élevé des enfants prématurés étaient en dessous du centile 10 selon les normes de la population typique, ce qui pourrait constituer un indice d'identification de risque de délais langagiers.

Pris ensemble, nos résultats offrent une vision plus détaillée et nuancée de l'acquisition langagière précoce des enfants nés à terme, et aident à mieux comprendre la contribution relative de l'input environnemental (i.e. exposition à input visuel et auditif non filtré) et la maturation neuronale à cette trajectoire développementale.

Abstract

Early speech perception in preterm and fullterm infants

Prematurity is currently an important public health problem in the world that affects 1 in 10 babies worldwide every year. In France, preterm birth has steadily increased from 5.7% in 1995 to 7.4% in 2010. Research has demonstrated that prematurely born children are more susceptible to encounter some difficulties in language development and other cognitive domains than children born fullterm. To date, knowledge on early language abilities in preterm infants remains limited. The first goal of this doctoral research was to specify different speech perception abilities in the first two years of life in preterm infants, comparing their abilities to those of fullterm infants of the same postnatal age. The second goal was to investigate whether degree of prematurity modulates linguistic performance across preterm infants.

This thesis is organized in three experimental parts. First, we explored word segmentation (the ability to extract word forms) from fluent speech, an ability that is related to lexical acquisition. Our findings showed that basic segmentation abilities are in place in monolingual preterm infants at 6 months of postnatal age (Exp. 1), since they segment monosyllabic words just like their postnatal (Nishibayashi, Goyet, & Nazzi, 2015) and maturational age (4-month-olds; Exp.2) fullterm peers. However, we also found differences with fullterms. While 6-month-old preterms segment embedded syllables as fullterms do (Nishibayashi et al., 2015), the direction of the effect is reversed, suggesting differential processing mechanisms (Exp. 3). Moreover, at 8 months postnatal age, we failed to find evidence for a consonant bias in recognition of segmented word forms (Exp. 4) as found for fullterms of the same age (Nishibayashi & Nazzi, 2016). Nevertheless, French-dominant bilingual populations were found to segment monosyllabic words in French at 6 months, whether being born pre- or full-term (Exp. 5).

In the second part, using eye-tracking techniques, we measured preterm and fullterm infants scanning patterns of a talking face in the native (French) and a non-native (English) language. We found that preterm infants at 8 months postnatal age show different looking behavior than their fullterm counterparts matched on postnatal and maturational age. Compared to fullterm infants who showed different scanning pattern of a face speaking in the two languages, preterm infants showed similar scanning patterns for both languages (Exp. 6). These differential gaze patterns provide

a first step to characterize the developmental course of audiovisual speech perception in preterm infants.

The third part focused on lexical development. Our results show that preterm infants recognize familiar word forms at 11 months postnatal age (Exp. 7), hence at the same postnatal age as fullterm infants (Hallé & de Boysson-Bardies, 1994). With respect to word production at around 24 months of postnatal age (Exp. 8), we found that preterm infants have smaller vocabularies than fullterms of the same postnatal age, but as a group have similar levels as their fullterm, maturational age peers. However, more preterm infants were below the 10th percentile than expected based on (fullterm) norms, which might constitute an index for early identification of (preterm) infants at risk for linguistic delays.

Taken together, our results help us build a more detailed and nuanced picture of early language acquisition in preterm infants, and better understand the relative contribution of environmental input (i.e. exposure to unfiltered auditory and visual input after preterm birth) and brain maturation on this developmental trajectory.

Acknowledgements – Remerciements

When I started this research work, I was mostly worried about how difficult it would be to recruit enough preterm infants for the experiments. Without them, this dissertation would not have been possible. This is the reason why I would first like to thank all the mothers of preterm babies who, despite being overwhelmed with all kind of medical appointments, they voluntarily contributed with their children to this research.

During the three years I have been carrying out this thesis, I have had the pleasure of working under the supervision of Thierry Nazzi. Thank you, Thierry, for your great mentorship, for being always available for whatever we need, for answering many of my questions, for asking me many others, and for your sense of humour, which is also very important to build a good mentor-student relationship. In this journey, I have also grown a lot intellectually thanks to Henny Yeung. In particular, I would like to thank Léo Nishibayashi for all his help when I arrived, by showing me how many things work in a babylab: from how to recruit participant to how to test them. Thank you, Lionel and Katie for answering many of my questions on data analyses.

I would like to take this opportunity to thank the members of my reading committee, Laura Bosch, Sharon Peperkamp, Alessandra Sansavini, and Bahia Guellaï for their careful reading of the manuscript and for their feedback and suggestions.

I think I have been very lucky to have a great work atmosphere. This is why I would like to thank all my colleagues from the babylab, we all contribute to it and I must acknowledge that this is highly motivating. Merci également pour tous vos encouragements pendant la période d'écriture !

Special thanks also to my colleagues and friends from the « bureau de doctorants », where we share many professional but also personal life issues. Thank you Mélanie, María, Caterina, Oytun, Lisa, and Andrea for your help and support!

I would also like to thank many people who have been involved in the recruitment of preterm babies for my studies: the Hôpital Robert Debré (Dr. Valérie Biran and Dr. Olivier Baud), the LSCP (merci spécialement à Anne-Caroline Fievet), l'association SOSPréma, and all my colleagues who have forwarded me emails during their own recruitments when they had a preterm candidate.

This thesis was funded by LABEX EFL. I am grateful for their financial support.

Lastly, I would like to thank my friends and family who in the distance have encouraged me through a lot of messages. Gracias Anna, Gloria, Ana y Rubén. Me gustaría dedicar esta tesis a mis padres, por ser el mayor apoyo, aunque sea en la distancia. Merci Baptiste, pour tout ton amour et soutien quotidien.

Enfin, merci au médecin Stéphane Tarnier, l'inventeur de la couveuse qui a contribué à sauver beaucoup des bébés nés prématurément.

TABLE OF CONTENTS

| | |
|---|----|
| GENERAL INTRODUCTION | 1 |
| 1. Preterm Birth: An Overview | 3 |
| 2. Background | 4 |
| 2.1. Definition and Categorization | 4 |
| 2.2. Risk Factors for Preterm birth | 5 |
| 2.3. Prematurity in Numbers | 6 |
| 2.4. Health Impact of Preterm Birth | 7 |
| 2.4.1. Respiratory Disorders | 7 |
| 2.4.2. Cardiovascular Disorders | 8 |
| 2.4.3. Central Nervous System Disorders | 8 |
| 2.4.4. Vision | 9 |
| 2.4.5. Gastrointestinal tract | 10 |
| 2.5. Brain architecture and neurodevelopmental outcomes | 10 |
| 3. Speech and Language | 12 |
| 3.1. Early development in fullterm infants: prenatal period and infancy | 12 |
| 3.1.1. Main stages of development of the auditory system and speech perception in the uterine environment | 12 |
| 3.1.2. Typical language acquisition: Fetal memory, neonatal speech perception, and first acquisitions | 14 |
| 3.1.2.1. Prosodic/Suprasegmental information | 16 |
| 3.1.2.2. Phonetic/Segmental information | 17 |
| 3.1.2.3. Word-related abilities | 19 |
| 3.1.2.3.1. Segmentation | 19 |
| 3.1.2.3.2. Word Comprehension | 22 |
| 3.1.2.3.3. Face-to-face interactions | 23 |

| | |
|--|-----|
| 3.2. Preterm birth: transition from the womb to the extrauterine environment..... | 26 |
| 3.2.1. Preterm infants and language acquisition: Toddlerhood and childhood..... | 32 |
| 3.2.1.1. Standardized tests of language assessment..... | 32 |
| 3.2.1.2. Experimental studies..... | 34 |
| 3.2.2. Preterm infants and language acquisition: Infancy..... | 36 |
| 3.2.2.1. Prosodic/Suprasegmental information..... | 37 |
| 3.2.2.2. Phonetic/Segmental information..... | 40 |
| 3.2.2.3. Word-related abilities..... | 43 |
| 3.2.2.3.1. Segmentation..... | 43 |
| 3.2.2.3.2. Comprehension..... | 45 |
| 3.2.2.3.3. Face-to-face interactions..... | 46 |
| 3.2.2.4. Conclusion..... | 46 |
| 4. Objective of the present thesis..... | 47 |
| CHAPTER 1. Early segmentation abilities in preterm infants..... | 51 |
| 1. Experiment 1. Monosyllabic words: Preterm infants at 6 months..... | 54 |
| 2. Experiment 2. Monosyllabic words: Fullterm infants at 4 months..... | 64 |
| 3. Experiment 3. Embedded syllables: Preterm infants at 6 months..... | 74 |
| 4. Experiment 4. Emergence of a consonant bias? Preterm infants at 8 months..... | 82 |
| 5. Experiment 5. Monosyllabic word segmentation in bilingual preterm and fullterm infants at 6 months..... | 90 |
| 6. Chapter Discussion..... | 100 |
| CHAPTER 2. Audiovisual Speech Perception..... | 101 |
| 1. Experiment 6. Visual Scanning of a Talking Face in Preterm and Fullterm Infants..... | 105 |

| | |
|---|------------------------------------|
| CHAPTER 3. Word-form Recognition and Word Production..... | Erreur ! Signet non défini. |
| 1. Experiment 7. Word-form recognition at 11 months postnatal age | 128 |
| 2. Experiment 8. The appropriateness of the use of postnatal age or maturational age in the assessment of expressive vocabulary: word production at 24 months | 138 |
| 3. Chapter Discussion..... | 151 |
| GENERAL DISCUSSION..... | 155 |
| 1. Summary of results..... | 158 |
| 1.1. Infants born preterm segment syllabic units at 6 months postnatal age | 158 |
| 1.2. Do prematurity and bilingualism influence early word segmentation abilities? | 160 |
| 1.3. Early impact of prematurity on audiovisual speech..... | 162 |
| 1.4. Word abilities..... | 163 |
| 2. Postnatal or maturational age: Does prematurity differentially affect different subdomains? | 164 |
| 3. The role of degree of prematurity | 167 |
| 4. Biological factors and brain development..... | 168 |
| 5. Strengths and limitations..... | 170 |
| 6. Future directions..... | 172 |
| 7. General conclusion..... | 174 |
| REFERENCES | 177 |
| APPENDICES..... | 213 |

GENERAL INTRODUCTION

Much of the research on language development in children born preterm has focused on standardized measures of language. Few studies have looked explicitly at language acquisition during the first two years of life, a crucial period for language acquisition. The work conducted in the present dissertation looked at the relative contribution of postnatal age in speech perception abilities in healthy preterm infants. My work focused on three main areas: (a) segmentation abilities; (b) audiovisual speech perception, particularly of a talking face; and finally, (c) lexical recognition and production.

Prior to the experimental work, I will first provide an overview of important issues associated with preterm birth, from the factors related to a preterm delivery to its main health and neurodevelopmental implications. Next, I will present a review of auditory development and speech perception in the prenatal period and infancy in fullterm infants in order to set the typical developmental framework of early language acquisition. Then I will review preterm birth and the possible implications of an early transition from the womb to the extrauterine environment, followed by a review of the relevant literature on language acquisition during childhood and infancy. I will close the chapter by introducing the objectives of the present thesis, focusing on comparing speech perception abilities in preterm and fullterm infants in the first two years of life.

1. Preterm Birth: An Overview

Preterm birth refers to birth before 37 gestational weeks (GWs). Pregnancies are dated from the woman's last menstrual period and not from the date of conception¹. According to the World Health Organization (WHO), almost 1 in 10 babies around the world is born preterm, and in France, it represented 7.4 % of births in 2010 (Institut National de la Santé et de la Recherche Médicale). One of the goals of the WHO by 2025 is to reduce significantly the risk of prematurity, primarily because complications associated to preterm birth are the leading cause of death in the neonatal period and

¹Throughout this document we will refer to gestational weeks (GWs) as post-menstrual weeks.

the second cause in children under the age of 5 (the first one being malnutrition). Although there has been an increase in survival rates thanks to medical advances, this number is unequally distributed. In low-income countries, the rate of survival is much lower than in high-income ones. This prevalence of preterm birth constitutes a public health issue for several reasons. Children born premature frequently experience health problems, such as visual and hearing deficits, chronic lung disease as well as neurodevelopmental and behavioral impairments or delays. As a result, learning difficulties during childhood may emerge and, often, prematurity leaves a lasting effect until adulthood. The signs of prematurity can be perceived in a number of ways. Studying early speech perception abilities, as this work does, provides evidence of the specific developmental trajectory of preterm children and raises questions about when and how these children will reach important linguistic milestones.

2. Background

2.1. Definition and Categorization

A fullterm human pregnancy lasts 40 GWs, although most births usually occur between 37 and 42 GWs. Therefore, a premature birth is defined as a birth before 37 completed GWs or 259 days since the first day of a woman's last menstrual period (WHO, 2012; Beck et al., 2010). Preterm birth is usually divided into subcategories: childbirth before 28 GWs is defined as extremely preterm, before 32 GWs as very preterm, between 32 and 34 GWs as moderate preterm and between 34 and 36 GWs as late preterm (See Figure 0.1). Birth weight has also been used to characterize infants, especially before the use of prenatal ultrasound allowing a more accurate estimation of the gestational age. Birth weight of less than 2,500 grams is defined as low birth weight, irrespective of gestational age (WHO). A birth weight of less than 1,500 grams is considered as very low birth weight and less than 1,000 grams as extremely low birth weight. Although there is a high correlation between gestational age and birth weight, not all small babies are premature. For example, in developing countries there is a higher proportion of infants born with low weight due to malnutrition. An infant whose birth weight is too low for their gestational age is considered small for gestational age (SGA), usually below the 10th percentile for its gestational age. One of the causes of SGA is a condition in which the unborn baby is

not growing at a normal rate inside the womb, also known as intrauterine growth restriction.



Figure 0.1. Degrees of prematurity according to gestational age and birth weight

2.2. Risk Factors for Preterm birth

Much remains unknown about the exact causes behind a premature birth. It can occur spontaneously or it can be initiated by obstetricians. Medical factors that play an important role in preterm delivery include intrauterine and intra-amniotic infections, a short cervix and pre-eclampsia (a condition associated to high blood pressure and protein in the urine). Likewise, extruterine infections such as malaria and pneumonia are also contributors to preterm labor (Romero et al., 2014). Fortunately, medical advances have improved neonatal care, leading to an increase of infants born alive before fullterm, along with a decrease in mortality rate. This means, in turn, that there are more surviving babies that are born at decreasing gestational age (as early as 22-23 GWs). However, the potential implications of a human being developing outside the womb are still not fully understood, an issue that requires an important amount of research in different developmental domains.

In addition to medical conditions, other factors have been associated with a higher risk of premature birth, such as socioeconomic, environmental, and maternal factors. Socioeconomic and environmental factors include parental educational status,

family income, lack of prenatal care or lifestyle aspects, for instance, maternal stress from excessive workload, smoking, alcohol consumption or illicit drug use. Maternal age (young or advanced), low body mass index, and history of previous premature births are other precursors of increased preterm birth risk. Moreover, the availability of assisted conception and fertility treatments in many high-income countries has raised the number of twins and triplets. Multiple pregnancies often involve a uterine overdistension, increasing the probability of preterm birth up to 10 times compared to singleton births (Blondel, Macfarlane, Gissler, Breart, & Zeitlin, 2006).

2.3. Prematurity in Numbers

One in every ten births worldwide is preterm so that, every year, approximately 13 million infants are born prematurely (for the prevalence of preterm birth across world regions, see Table 0.1.). Lower incidence of prematurity is related to improvements in socioeconomic, prenatal care, overall better health condition, and educational level, more notably in high income countries. Noteworthy, there has been an increase in the number of preterm births worldwide in the past two decades (WHO). In France, there has been a considerable increase in the last fifteen years from 5.7% in 1995 to around 7.4% in 2010. From that percentage of 2010, 5% constitute extremely preterm births (<28 GWs), 10% very preterm births (28-32 GWs) and 85% moderate and late preterm births (32-36 GWs) (Institut National de la Santé et de la Recherche Médicale). The percentage of live births with a birth weight under 2,500 grams in 2010 was 6.4%, from which 0.8% were born with less than 1,500 grams and 5.6% between 1,500 and 2,499 grams.

Table 0.1 Estimated preterm birth rates in 2010, adapted from Blencowe et al., 2012.

| Region | Estimated mean preterm birth rate (%) |
|---------------------------|--|
| Southeastern Asia | 13.6 |
| Southern Asia | 13.3 |
| Sub-Saharan Africa | 12.3 |
| Caribbean | 11.2 |
| Western Asia | 10.1 |
| Caucasus and Central Asia | 9.2 |
| Developed regions | 8.6 |
| Latin America | 8.4 |
| Oceania | 7.4 |
| Northern Africa | 7.3 |
| Eastern Asia | 7.2 |

The main reasons for this trend are not well understood, but it seems reasonable to associate it to advances in neonatal and perinatal care allowing a greater number of babies born at lower gestational ages to survive, the advanced maternal average age, or risks associated with fertility treatments.

2.4. Health Impact of Preterm Birth

If prematurity could be characterized with one word, it would be immaturity. At the moment a preterm infant is born, the organism is not ready for the transition to the outside world and doctors face considerable challenges to ensure the infant's survival (neurological, breathing, etc.). Preterm infants may go through prenatal and postnatal medical complications that include respiratory, cardiovascular or central nervous system disorders, and vision or digestive problems, among others, that will be briefly described in this section.

2.4.1. Respiratory Disorders

Most preterm infants are born with immature lungs which may require mechanical ventilation and supplemental oxygen. Prolonged oxygen delivery can cause mild-to-severe injury of the alveoli (e.g., inflammation), resulting in a form of chronic lung disease known as Bronchopulmonary Dysplasia. Some decades ago, this condition

was frequent in infants who were treated with high oxygen concentrations because they had hyaline membrane disease. The hyaline membrane disease refers to a syndrome caused by insufficiency of pulmonary surfactant production, which is a substance that prevents alveoli from collapsing, and reduces the effort needed to expand the lungs during breathing (Veldhuizen & Haagsman, 2000). Before innovations in the prenatal treatment that nowadays help prevent this syndrome by giving mothers corticosteroids to accelerate the production of pulmonary surfactant, many preterm infants died as a consequence of breathing difficulties. One case that deserves being mentioned is the last child of the United States President, John F. Kennedy, and Jackie Kennedy, who was born preterm and passed away due to hyaline membrane disease. His death was not in vain, since it led to important innovations in neonatal care.

2.4.2. Cardiovascular Disorders

Infants born preterm also suffer from heart problems, in particular, from patent ductus arteriosus. Usually, in the first few days after a fullterm infant is born, the connection between the aorta and the pulmonary artery closes. While in the womb, it remains open because it allows oxygen-rich blood to provide oxygen to the body. Once the infant has to use his lungs, the connection closes naturally. However, if the connection remains open (patent ductus arteriosus), the lungs receive extra blood flow that may lead to breathing difficulties and lung damage.

2.4.3. Central Nervous System Disorders

In addition to cardiovascular problems, bleeding may occur in the preterm brain, which can be detected using cranial ultrasound. It is called Intraventricular Hemorrhage (IVH) because the bleeding occurs in the cavities in the brain called ventricles (containing cerebrospinal fluid). It is thought that the vulnerability of the blood vessels in younger and smaller babies increases the risk of rupture, causing the blood to flow into the ventricles. There are four grades of IVH, from less to more severe damage (Papile, Burstein, Burstein, & Koffler, 1978). Grades 1 and 2 are the most common, and often do not entail further complications. Grades 3 and 4 reflect more serious damage (see Table 0.2).

Table 0.2. Description of degrees of intraventricular hemorrhages.

| Grade | Description |
|-------|---|
| 1 | Bleeding is confined in a small area of the ventricle (<10%). |
| 2 | Bleeding also occurs inside the ventricles (10-50%). |
| 3 | Ventricles are enlarged by the bleeding (>50%). |
| 4 | Bleeding into the brain tissues around the ventricles |

Another type of brain injury is Periventricular Leukomalacia (PVL) which involves the death of white matter around the lateral ventricles because of lack of blood flow or oxygen. Some of the infants who experience PVL may eventually develop cerebral palsy, depending on the degree of white matter damage.

2.4.4. Vision

Retinopathy of prematurity (ROP) is an eye disease caused by the abnormal development of retinal blood vessels, growing out of the retina. If the damage is severe, it can detach the retina and eventually can result in blindness. Infants born very preterm and those who have needed oxygen supply are more likely to develop ROP either because the retina is not receiving enough oxygen and tries to develop new vessels or because too much oxygen causes the vessels to grow abnormally. Nowadays, better monitoring of the levels of oxygen supplied has decreased the risk of developing ROP. There are five stages of ROP (see Table 0.3., adapted from Gole et al., 2005). Stages I and II correspond to mild and moderate abnormal blood vessel growth, and Stages III, IV, and V to severe damage.

Table 0.3. Description of different stages of retinopathy of prematurity.

| Stage | Description |
|-------|--|
| 1 | Mildly abnormal blood vessel growth |
| 2 | Blood vessel growth is moderately abnormal |
| 3 | Blood vessel growth is severely abnormal |
| 4 | Partial retinal detachment |
| 5 | Total retinal detachment |

2.4.5. Gastrointestinal tract

Necrotizing enterocolitis is a disease that affects the tissue in the inner lining of the intestine, causing the intestine to become inflamed. If the disease progresses, it can form a hole in the intestine leaking bacteria from the intestine onto other organs, producing infections. Although the exact cause is still unknown, it has been related to the immaturity of the organism.

To sum up, the preceding medical complications listed above represent the main problems that preterm infants face, with higher odds of suffering impairments as the degree of prematurity decreases. The following section will briefly review the literature on differences in preterm children's brain architecture, in an effort to give a more complete picture of their neurological development, on which their cognitive and linguistic development will partly depend.

2.5. Brain architecture and neurodevelopmental outcomes

Recent research in neuroscience has provided evidence of anatomical differences between preterm and fullterm infants, as a possible consequence of the disruption of the intrauterine environment for preterms, impacting the normal maturational processes of the brain. These include alterations in grey and white matter, in corpus callosal areas or in thalamic development (Ball et al., 2013; Inder, Warfield, Wang, Hüppi, & Volpe, 2005; Inder, Wells, Mogridge, Spencer, & Volpe, 2003; Iwata et al., 2012; Thompson et al., 2011; for a review, see de Kieviet, Zoetebier, van Elburg, Vermeulen, & Oosterlaan, 2012).

During the last trimester of pregnancy, gyrification begins (Vohr, 2014) and, overall, the cerebral cortex undergoes a period of rapid expansion and cortical folding (Engelhardt et al., 2015). In the last two decades, several studies have begun to focus on how preterm birth may impact this developmental process to test for possible abnormal or reduced cortical development (Ajayi-Obe, Saeed, Cowan, Rutherford, & Edwards, 2000; Dubois, et al., 2008). For instance, in Engelhardt et al. (2015), very preterm infants tested between 36 and 41 GWs were found to have lower values of global gyrification than fullterm newborns. It is important to note that none of the preterm infants had significant brain injury by the time of test. However, there were associations between the disruptions of cortical folding and clinical neonatal indexes.

Hence, the study demonstrates that there are important cortical differences between fullterm and preterm born infants at term equivalent age. Inder and colleagues (2005) also obtained quantitative measures from brain scans of a large cohort of preterm infants (over 100 participants) at term equivalent age. Their results revealed that deep nuclear grey matter volumes increase as a function of gestational age at birth. Importantly, these alterations in the cerebral structure were related to adverse neurodevelopmental outcome at 12 months.

The type of relationship between early brain structure and later cognitive outcomes that Inder and colleagues (2005) revealed, has also been found in children and adolescents born preterm (Feldman, Lee, Yeatman, & Yeom, 2012; Krishnan et al., 2007). In the domain of language, Feldman et al. (2012) found that properties of the white matter network were related to performance on several language and reading measures in the very preterm group but not in the fullterm group. Therefore, preterm individuals are at higher risk for developmental delay and negative behavioral outcomes (Delobel-Ayoub et al., 2009; Woodward, Clark, Bora, & Inder, 2012). This is particularly true for very preterm infants, although the role of the degree of prematurity is not always explored. On the other hand, it has been suggested that many of the language delays are the result of general cognitive problems, and not specifically language-related deficits (Barre, Morgan, Doyle, & Anderson, 2011; Wolke & Meyer, 1999).

As shown in this review, neurodevelopmental outcomes show that prematurity can lead to higher risk of later neurocognitive and developmental abnormalities. Investigating language acquisition is important, as neurological development, cognition and language skills are closely related and can have important consequences in future social and emotional growth (Moossavi & Panahi, 2017).

3. Speech and Language

3.1. Early development in fullterm infants: prenatal period and infancy

3.1.1. Main stages of development of the auditory system and speech perception in the uterine environment

The study of when and how speech perception emerges and changes in development is a fascinating research question in human development (Dehaene-Lambertz & Spelke, 2015). Research in this domain provides a great deal of information as to when and how the infant achieves certain abilities. Indeed, evidence suggests that language acquisition starts in the womb and depends on a combination of biologically constrained abilities and environmental factors (e.g., intra and extrauterine exposure to speech sounds). Biologically, the main structure of the ear, including the cochlea, is in place by 15 GWs and is functional by 23-25 GWs (Graven & Browne, 2008). During the last trimester of pregnancy, there is rapid brain growth linked with major organizational events, including the development of the neocortex, axons and dendrites linking nerve cells, and the development of synapses (Blackburn, 2016; Kinney, 2006). The fetus begins to perceive sounds from the placenta, the maternal organs and voice from 26-28 GWs (Chelli & Chanoufi, 2008). By 28-30 GWs, the neural connections to the temporal lobe are established, enabling the emergence of tonotopic columns in the auditory cortex (Graven & Browne, 2008). Tonotopic columns refer to the specific areas in the auditory cortex in which the neurons are tuned to certain frequencies. As gestational age increases, the neural pathways and myelination processes continue to develop while the auditory system continues to receive different sounds from the environment. Thus, by term date, the auditory system is the result of biological processes and auditory stimulation. But what does the fetus hear in the womb?

Unlike on land, when underwater, humans can hear through bone conduction. When sound travels through the air, it causes vibration in the bones of the middle ear. The sensory cells in the inner ear will capture the vibration and send electrical signals to the brain. Underwater, the sound gets to the inner ear through the eardrum, the bones in the middle ear and the mastoid. Although sound travels much faster underwater than on land, bone conductivity is less effective than air conductivity. Moreover, the fetus grows surrounded by body tissues and amniotic fluid that act as a low pass filter, attenuating higher frequencies. For this reason, intrauterine experience

mostly corresponds to low frequency sounds coming from the maternal organs and voice. Thus, the fetus can hear some speech, heartbeat, and digestive sounds from the mother during the last trimester of pregnancy (Fifer & Moon, 1989; Querleu, Renard, Versyp, Paris-Delrue, & Crèpin, 1988).

Starting in the 1980s, research measuring fetal movement or heart rate using ultrasonography demonstrated that the fetus increases movement and shows cardiac responses to acoustical stimuli (Lecanuet, Granier-Deferre, & Busnel, 1995; Lecanuet & Schaal, 1996). According to several studies, the fetus responds to auditory stimulation from 26 GWs, though the responses depend on several factors, such as intensity, frequency of stimulation and gestational age (Arabin, 2002). The fetus can mainly perceive low frequency sounds below 500 Hz (Moon, 2011) although, in the last weeks of gestation (35 GWs), fetuses respond to 3000 Hz pure tones (Hepper & Shahidullah, 1994). It has been suggested that responses observed from lower to higher sounds with increasing gestational age may be the result of the maturational development of the auditory system (Hepper & Shahidulla, 1994) or of the progressive thinning of the walls of the intrauterine lining (Querleu et al., 1988). Thus, as pointed out by Lahav and Skoe (2014), fetuses may develop normally until term by gradually developing their tonotopic maps from low to high frequencies. These auditory stimulations are thought to have an important role in the development of cochlear innervations. Building on these findings and assumptions, it is possible that the disruption of normal intrauterine development as a result of preterm birth has an effect in the development of the auditory system and its neural correlates.

In recent years, more advanced technological measures such as brain imaging techniques (e.g. functional magnetic resonance imaging –fMRI–, magnetoencephalography –MEG–, or fetal magnetoencephalography –fMEG–), have begun to record detection and discrimination of auditory stimuli between 28 and 34 GWs (Draganova et al., 2005; Jardri et al., 2012; Moore, 2002). For example, Draganova and colleagues (2005), using an oddball paradigm with standard tones intermixed with deviant ones, found auditory evoked field response to the deviant tones in 60% of fetuses between 33-36 GWs. Other studies have detected even earlier evidence of discrimination starting at 27 GWs and 28 GWs (Holst et al., 2005). These findings suggest that the auditory system is in place and functioning by the time most preterm infants are born (given that only 52% of those born between 22-26 GWs survive; Pierrat et al., 2017). Furthermore, the use of brain imaging techniques in the prenatal

period could be considered as a possible tool to further investigate the predictive value of early brain responses for later risks in auditory speech processing in infants at risk for later language delays. Before reviewing the literature on speech perception in preterm children and infants, we will first focus on research on typical language acquisition in monolingual fullterm infants. We will start by describing fetal memory learning and neonatal speech perception, and the language developmental milestones in the first year of life, as a point of reference to understand language development in preterm infants.

3.1.2. Typical language acquisition: Fetal memory, neonatal speech perception, and first acquisitions

As fragile and helpless as newborns might look, they have remarkable linguistic abilities at birth. A number of studies in the last three decades have shown that fullterm newborns have accumulated fetal memory, as revealed by changes in behavior (looking times, non-nutritive sucking). They can remember and recognize the voice of their mother (DeCasper & Fifer, 1980; DeCasper & Spence, 1986), distinguish the rhythmic features of their native language(s) (Abboub, Nazzi, & Gervain, 2016; Mehler et al., 1988; Nazzi, Bertoncini, & Mehler, 1998; Byers-Heinlein, Burns, & Werker, 2010; Ramus, Hauser, Miller, Morris, & Mehler, 2000), they are sensitive to prosodic boundaries (Christophe, Dupoux, Bertoncini, & Mehler, 1994; Christophe, Mehler, & Sebastián-Gallés, 2001) and to acoustic cues differentiating lexical and grammatical words (Shi, Werker, & Morgan, 1999), and they can distinguish lexical stress patterns (Sansavini, Bertoncini & Giovanelli, 1997) and pitch contours (Nazzi et al., 1998). What do these abilities tell us about the prenatal language experience?

DeCasper and Spence (1986) demonstrated for the first time that, from 33 weeks of gestation onwards, the fetus is sensitive to the mother's voice and rhythm. In DeCasper and Spence's (1986) experiment, mothers were asked to read aloud a story from 33 GWs until birth. Newborns preferred the story previously read by the mother to a story that was never recited to them. More recently, in a similar study, mothers were asked to start reciting a passage at 28 GWs and to stop by 34 GWs (Krueger & Garvan, 2014). The heart rate of the fetus was measured every two weeks between 28 and 38 GWs. By 34 GWs, a sustained heart rate deceleration for the previously recited story emerged, and by 38 GWs it was stable. This provides evidence of learning after accumulated linguistic experience across the prenatal period that persists in memory

for (at least) a few weeks. These behavioral findings are further supported by electrophysiological studies revealing distinct responses to the maternal and a stranger's female voice at birth (deRegnier, Wewerka, Georgieff, Mattia, & Nelson, 2002; Therien, Worwa, & Mattia, 2004; Beauchemin et al., 2010).

As shown by psycholinguist researchers, infants make use of the rhythmic cues of the language they have been exposed to prenatally. According to their rhythm, languages have been (traditionally) classified in three types: syllable-timed (e.g. French, Spanish, Italian, Catalan), stress-timed (e.g. English, Dutch, German) and mora-timed languages (e.g. Japanese, Tamil), having the syllable, the stress, and the mora, as rhythmic units, respectively (Abercrombie, 1967). The evidence from studies showing that newborns can discriminate two rhythmically different languages (Byers-Heinlein et al., 2010; Mehler & Christophe, 1994; Nazzi et al., 1998) and prefer their native language (Mehler et al., 1988; Moon, Panneton-Cooper, & Fifer, 1993), suggests that they are sensitive to the rhythmic unit of their native language. When speech is low pass filtered and thus only prosodic properties are available, similarly to the conditions of the intrauterine environment, newborns still prefer the native language of the mother (Mehler et al., 1988; Moon, Panneton-Cooper, & Fifer, 1993; Nazzi et al., 1998). Altogether, converging behavioral and electrophysiological evidence suggests that the fetus is sensitive to auditory information, linguistic stimulation and that some of the prosodic properties of the mother's voice and language (pitch, rhythm, intensity) are learned during pregnancy.

Another question raised by researchers is whether the human brain is inherently "hardwired" to process speech or whether the brain has the capacity to learn. For instance, newborns have been shown to process phonetic information, as they can discriminate CV syllables based on the onset place of articulation of the consonant, as well as on the vowel features (Bertoncini, Bijeljac-Babic, Blumstein, & Mehler, 1987). Bertoncini and colleagues (1987), suggest that their findings are compatible with Stevens and Blumstein's (1978, 1981) idea that "infants are born with an innate predisposition for extracting invariant acoustic properties, which provide a framework for perceiving phonetic dimensions of speech". Likewise, the idea that humans are born with a language bias is supported by studies comparing speech processing with the processing of backward speech and non-speech (e.g. sine-wave speech; Ramus et al., 2000). Newborns show greater left hemisphere activation for forward speech compared to backward speech (Peña et al., 2003) and during the first month of life, infants show

increasing left hemisphere dominance in auditory perception (Zhang, Li, Zheng, Dong, & Tu, 2017). This left hemisphere specialization is presumed to be strongly related to the language centers of the brain, Broca's and Wernicke's areas, which are located on the left hemisphere (Armstrong, Schleicher, Omran, Curtis, & Zilles, 1995). Nonetheless, controversies remain about the origin of hemispheric specialization for speech and what linguistic aspects may drive asymmetrical activation (for a review, see Hickok & Small, 2015).

This initial predisposition for speech from very early on rapidly evolves as infants gradually acquire knowledge about their native language. In order to identify spoken words in the environment, young infants rely on segmental features (phonetic information, that is, vowels and consonants) and suprasegmental features (rhythm, stress, intonation) of the language in their environment. By detecting and using segmental (phonetic information) and suprasegmental cues (prosodic cues), infants can process relevant information in speech. This includes categorizing speech sounds, identifying lexical units in the speech stream and learning new words in a communicative social context and learning the syntax of their native language, an issue which will not be discussed in the present dissertation. Attaining these abilities are crucial milestones for later linguistic development such as vocabulary acquisition, a domain where preterm children have been found to remain behind fullterm children.

3.1.2.1. Prosodic/Suprasegmental information

We now turn to the processing and use of suprasegmental cues (prosodic features). As previously mentioned, at birth, infants are able to discriminate two rhythmically different languages (Nazzi et al., 1998), and they also detect prosodic cues that are aligned with word boundaries (Christophe, et al., 1994), but it is not until 4-5 months that they discriminate their native language from a rhythmically-similar language (Bosch & Sebastián-Gallés, 1997; Nazzi, Jusczyk, & Johnson, 2000). Prosodic cues span various linguistic levels including lexical, semantic, syntactic or pragmatic.

For instance, lexical stress is useful for word recognition and lexical access or for narrowing down the grammatical category (e.g. noun: REcord vs. verb: reCORD). With respect to the word recognition issue, lexical stress has a highly predominant pattern in some languages, and this cue can be used to detect word boundaries. In English or German, for example, 90% of bisyllabic words are trochaic, i.e. the stress is on the first syllable (e.g. DOctor; Cutler & Carter, 1987). Evidence has demonstrated

that native English speakers consider that the onset of the word is marked by an initial strong syllable (Cutler & Norris, 1988). During the first year of life, infants acquiring a stress-based language, such as German, show discrimination of trochaic (strong-weak, e.g., DOctor) versus iambic (weak-strong, e.g., guiTAR) words at 4 months and preference for the lexical pattern of German at 6 months (Herold, Höhle, Walch, Weber, & Obladen, 2008; Höhle, Bijeljac-Babic, Herold, Weissenborn, & Nazzi, 2009; Skoruppa et al., 2009). This bias for trochaic words is not found in 6-month-old French-learning infants despite discriminating both patterns at the behavioral level and at the electrophysiological level at 4-6 months of age (Friederici, Friedrich, & Christophe, 2007; Höhle, et al., 2009), with a decrease in discrimination by 9-10 months (Bijeljac-Babic, Serres, Höhle, & Nazzi, 2012; Skoruppa et al., 2009).

3.1.2.2. Phonetic/Segmental information

We will first describe the mechanisms involved in the perception of segmental cues and how they change in language acquisition. Phonemes are acoustic elements that are linguistically contrastive so that, for example, if two words differ only by one speech sound they can be differentiated thanks to that phoneme, as in the English words /pɪn/ vs /bɪn/, rendering this difference linguistically significant in English. In fact, /p/ and /b/ belong to the same natural class because they share all phonetic features (manner, place of articulation, continuant) except for one (voicing): /p/ is voiceless whereas /b/ is voiced. Speakers of different languages categorize these sounds as different phonological categories (Lisker & Abramson, 1967). This is because the native language shapes the way speakers categorize speech sounds depending on where boundaries are placed, for example, on the continuum /b-p/ (Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992). In the first months of life, young infants have a language general perceptual ability to discriminate speech sounds, and they do so in a categorical way (Eimas, Siqueland, Jusczyk, & Vigorito, 1971). However, as adults, our brain is already “wired” to language-specific contrastive categories and we exhibit low sensitivity to differences between non-native contrasts. For example, Japanese adults have trouble distinguishing the consonant contrast /r-l/ whereas Japanese infants are able to discriminate this contrast until the second half of the first year (Kuhl et al., 2006; Miyawaki et al., 1975).

The decline in the perception of contrasts that are irrelevant in the repertoires of the native languages applies equally to vowel and consonant contrasts. Regarding

vowel contrasts, 4- to 6-month English-learning infants are able to discriminate two close vowels (e.g. German /y-u/ and /Y-U/) while 6- to 8-month-olds no longer discriminate them (Kuhl, 1991, Polka & Werker, 1994). Similarly, Spanish monolingual infants are able to perceive a vowel contrast in Catalan (/e/-/E/) at 4 months, but by 8 months they fail at perceiving this difference (Bosch & Sebastián-Gallés, 2003). Regarding consonant contrasts, this decline emerges a little bit later than for vowels, by 10-12 months (Werker & Tees, 1984, 2005). Similar to the example of Japanese adults who have difficulties distinguishing /r-l/, Werker and colleagues have shown that 6- to 8-month-old English-learning infants distinguish the retroflex /Da/ from the dental /da/, a Hindi contrast, but at 10-12 months they are unable to perceive this difference. Why, then, do we lose the ability to discriminate non-native contrasts? It has been suggested that as infants become more attuned to the sounds of their native language, becoming more competent listeners of native language sounds (Rivera-Gaxiola, Silva-Pereyra, & Kuhl, 2005), they lose sensitivity to perceive some foreign contrasts, depending on how these contrasts map onto the phonological system of the native language (see Perceptual Assimilation Model, Best, McRoberts, & Sithole, 1988). This is how, throughout development, the perceptual mechanisms in place at birth gradually specialize in the processing of the native language from the age of 6 months. How this process happens is still a debated issue, but possible mechanisms include tracking distributional information of phoneme realization in the acoustic space (Maye, Werker, & Gerken, 2002) or using consistent links between word forms and objects (Yeung & Werker, 2009; Yeung & Nazzi, 2014).

Besides phonemes, infants also have to learn other phonological properties, such as allophonic and phonotactic cues. Allophony is a language-specific cue that refers to the existence of possible variants of the same phoneme in different contexts. For example, in English, the phoneme /t/ is pronounced differently at the initial and final position of a word. By 2 months, infants are already sensitive to allophonic differences (Hohne & Jusczyk, 1994). The second language-specific cue, phonotactics, refers to the possible speech sequences of phones within and between words in a language. While in English [/wz/] is rarely found inside of words, [/st/] is very frequent (e.g. astronaut). Results of several studies of the acquisition of phonotactics have shown that infants become sensitive to the phonotactic patterns of their native language by 9-10 months (for English: Jusczyk, Friederici, Wessels, Svenkerud &

Jusczyk, 1993; for French: Nazzi, Bertoncini, & Bijeljac-Babic, 2009; Gonzalez-Gomez & Nazzi, 2012b; for Spanish/Catalan: Sebastián-Gallés & Bosch, 2002).

In summary, in the past few decades, our knowledge on infants' perception of segmental information has increased considerably. As infants grow older, they experience a decline in perceiving non-native phonetic contrasts parallel to an increase to native ones, show their abilities of tracking distributional information, and become more sensitive to phonotactic patterns of their native language. These mechanisms are useful to continue developing other speech abilities, including the identification of word forms from fluent speech and later lexical development.

3.1.2.3. Word-related abilities

3.1.2.3.1. Segmentation

One of the abilities that infants develop during the first year is segmenting fluent speech, that is, identifying words (or more precisely, word-forms) in the speech stream. Numerous studies have confirmed that infants from different language backgrounds start segmenting words by 6 to 8 months of age (US English: Jusczyk & Aslin, 1995; Jusczyk, Houston & Newsome, 1999; German: Höhle & Weissenborn, 2003; French: Goyet, Nishibayashi, & Nazzi, 2013; Nazzi, Mersad, Sundara, Iakimova, & Polka, 2014; Nishibayashi, Goyet, & Nazzi, 2015; Spanish and Catalan: Bosch, Figueras, Teixidó, & Ramon-Casas, 2013), to the exception of British English at 10.5 months (Floccia et al., 2016).

Infants acquiring a stress-based language that has a predominant lexical stress pattern show a preference for such stress pattern and are also able to segment such words earlier than those having a different stress pattern. In a study investigating English-learning 7.5-month-old infants' ability to segment bisyllabic words, Jusczyk, Houston, and Newsome (1999) found that infants could segment bisyllabic trochaic words but not iambic words, the trochaic pattern corresponding to the most frequent pattern in English. It is only at 10 months that infants could segment iambic words. Other studies on stress-based languages have demonstrated similar results of trochaic word segmentation (German: Höhle & Weissenborn, 2003; Dutch: Houston, Jusczyk, Kuijpers, Coolen, & Cutler, 2000; Kooijman, Hagoort & Cutler, 2005; Kuijpers, Coolen, Houston & Cutler, 1998).

In other populations acquiring syllable-timed languages such as French, Spanish, or Catalan, research has explored whether the ability to extract words matched the

rhythmic unit, that is, the syllable (Spanish and Catalan: Bosch et al., 2013; French: Gout, 2001; Nazzi, Iakimova, Bertoncini, Frédonie, & Alcantara, 2006; Nazzi et al., 2014; Nishibayashi et al., 2015; Polka & Sundara, 2012; Goyet, et al., 2013). Syllabic segmentation in French has been found at 6 months, showing that these infants segment the syllabic unit independently of the lexical unit (Nishibayashi et al., 2015). In other words, French-learning infants are successful in segmenting consonant–vowel monosyllabic words from fluent speech, but they also segment CV syllables embedded in longer words (when the familiarization phase is extended). It is only at 8 months that they segment bisyllabic words (Nishibayashi et al., 2015). These results suggest that the syllable is the earliest linguistic structure segmented by French-learning infants and that they use the syllable as a cue for segmenting words. Altogether, the evidence from these cross-linguistic studies has revealed that infants make use of prosodic cues available in the input to extract words from the speech stream.

Infants also use cues other than the stress unit of their native language for word segmentation, such as allophonic and phonotactic cues. For allophony, in a study at 10.5 months of age, infants were familiarized with either ‘nitrates’ or ‘night rates’ and tested on passages containing the familiar pattern or the allophonic one. They showed longer looking times to the passage containing the familiarized word, suggesting that the distribution of the allophones helps locate word boundaries by identifying whether two consecutive syllables belong or not to the same word (Jusczyk, Hohne, & Bauman, 1999).

Regarding phonotactics, several studies establish that 9-10-month-old infants can exploit phonotactic cues to segment word forms from fluent speech (for English: Mattys, Jusczyk, Luce, & Morgan, 1999; Mattys & Jusczyk, 2001; for French: Gonzalez-Gomez & Nazzi, 2012b). For instance, Mattys and Jusczyk (2001) manipulated the probability of consonant–consonant clusters at the onset and offset of words in English to test 9-month-old infants’ ability to detect word boundaries. Their results showed that infants looked significantly longer to words that had a higher consonant–consonant probability than to those having a lower probability. Similarly, French-learning infants use their phonotactic knowledge to segment words by 10 months (Gonzalez-Gomez & Nazzi, 2012b). They were first familiarized with two passages, one containing a frequent labial–coronal structure in French (e.g. /bat/) and the other one containing a coronal–labial (e.g. /tap/) less frequent structure. Then, they were tested on the two target words and two control pseudowords that had the labial–coronal or the coronal–labial

pattern. Infants showed longer looking times to the labial–coronal items, demonstrating that they can segment words that have a frequent phonotactic pattern in their language.

At the same time, a detailed phonetic perception is important for the detection of phonotactic patterns. Phonotactic patterns refer to the possible combinations of sounds in a language. For instance, in English, the string /-str-/ is more frequent in the initial than in the final position of a word. This information about phonotactic regularities helps infants find the onset and offsets of words by the age of 9 months (Friederici & Wessels, 1993; Jusczyk, et al., 1993; Jusczyk & Luce, 1994). However, in order to detect the phonotactic regularities of the language, infants have to be able to track the distributional information available in the speech stream. In their original Headturn Preference Procedure (HPP) study, Saffran, Aslin, and Newport (1996) investigated whether 8-month-old infants could use statistical information to segment fluent speech. Infants were presented with a 2-minute continuous artificial speech stream containing 4 trisyllabic nonwords (e.g. tupiro, golabu) repeated in a random order with no pauses or prosodic cues in the sequence. The transitional probability of syllables within words was 1.0 (as the three syllables in each word were always presented in that order) and the transitional probability between words was 0.33 (given that the syllable in the final position could be followed by three other possible initial syllables). In the test phase, infants were presented with the familiar trisyllabic nonwords or with novel nonwords made up of syllables present in the stream but in a different order. There was a significant novelty effect for the novel nonwords, indicating that infants had tracked the serial order of the syllables. Similar results were found when another group was presented in the test phase with the familiar nonwords and part-words made up of two syllables of a word, and a third one that belonged to a different word. The second experiment added to the first one that, besides tracking serial order, infants also compute between-syllable probabilities.

The seminal work of Saffran and colleagues (1996), and numerous studies over the last two decades, have demonstrated that infants are capable of learning and then recognizing the statistical structure of a combination of syllables, thus computing and extracting regularities of linguistic patterns (Aslin, Saffran, & Newport, 1998; Gomez, 2002; Lany & Saffran, 2010; Maye, Werker, & Gerken, 2002). There is also evidence that statistical learning is not language-specific, but it is a general cognitive mechanism applying to other non-linguistic domains as well (e.g., visual: Baker, Olson, & Behrmann,

2004; spatial: Goujon & Fagot, 2013; music: Saffran, Johnson, Aslin, & Newport, 1999). Furthermore, this mechanism is not unique to humans, since it is also present in other species, such as cotton-top tamarin monkeys and rats (e.g., Toro & Trobalón, 2005). While there is a general consensus that statistical cues are used for language acquisition, much remains to be further explored as to how this information interacts with other linguistic cues (prosody, semantics, etc.).

3.1.2.3.2. Word Comprehension

In order to understand the meaning of a word, infants first have to go through the process of recognizing its word form. Second, they have to associate it to the object it corresponds, a task that is not easy since, as remarked by De Saussure (1916), the sign (i.e. the object or language unit conveying meaning) results from the arbitrary association between the signifier (i.e. a sound, word or image), and the signified (the mental concept). Research in the last decades has investigated these two processes, one belonging to the auditory and the other to the audiovisual domain.

In the auditory domain, infants' recognition of familiar words has been tested by measuring the preference to listen to familiar over other type of words. These studies have demonstrated that by 5 months French-learning infants recognize their names (English: Mandel, Jusczyk & Pisoni, 1995; French: Bouchon, Floccia, Fux, Adda-Decker, & Nazzi 2015) and by 11 months they prefer to listen to a small list of familiar words over infrequent words or pseudowords (Hallé & de Boysson-Bardies, 1994; Poltrock & Nazzi, 2015). This finding was extended to infants from different language environments (for Dutch: Swingley, 2005; for English: Vihman, Nakai, DePaolis, & Hallé, 2004). Even before 11 months, English-learning infants can recognize a list of word forms if they have been previously trained with them during the age of 8 months (Jusczyk & Hohne, 1997). Furthermore, at 6-8 months, they can also segment new words more easily if a familiar word is placed next to them in the speech stream (Bortfeld, Morgan, Golinkoff, & Rathbun, 2005; Mersad & Nazzi, 2012).

In the audiovisual domain, infants actually demonstrate word comprehension in the first year of life. They are presented with two images first in silence, and then they are presented with a word corresponding to one of the images. If infants increase their looking to the target object, it is considered that infants have understood the word. At 6 months, they already associate the words "mommy" or "daddy" to the image of their parent (Tincoff & Jusczyk, 1999), understand body-part words to the appropriate image

(Tincoff & Jusczyk, 2012), and some familiar objects (Bergelson & Swingley, 2012). However, most of the studies focusing on word comprehension have been carried out during the second year of life. Besides studying the accuracy rate of infants at different ages, these studies have also measured the speed of recognition. Interestingly, one study investigating the role of the socioeconomic (SES) status of the family in children's word recognition abilities has demonstrated that low SES can represent a disadvantage as early as at 18 months (Fernald, Marchman, & Weisleder 2013). This study demonstrated that 24-month-olds from lower-SES had accuracy rates and processing efficiency similar to that of 18-month-olds from higher-SES rather than that of their same age higher-SES peers. Thus, significant differences in SES can have an impact in language acquisition and language growth, from at least, the second year of life.

While these discoveries have provided important knowledge about word recognition during the first two years of life in the last two decades, more recent research has started to document the developmental trajectory during face-to-face interactions and the role that social cues play in this process.

3.1.2.3.Face-to-face interactions

Another aspect that is crucial for language acquisition (for phonetic learning and particularly for word learning) is social engagement as reflected by joint attention and gaze following (Carpenter, Nagell, Tomasello, Butterworth, & Moore, 1998; Morales, Mundy, & Rojas, 1998). This refers to the ability to alternate gaze between the interlocutor and a third element, for example, an object. At birth, infants can better perceive objects that are approximately at 19 centimeters from their focus (Haynes, White, & Held, 1965) corresponding to the distance in face-to-face interactions between the mother and the infant, reducing the amount of visual information that the infant has to assimilate (due to the infant's visual developmental restrictions). It is approximately at 5 to 6 months that infants learn to follow the gaze of an adult towards an object (Morales, et al., 1998).

The particularity of audiovisual speech perception is that, while auditory stimulation is available to the fetus, visual stimulation begins after birth (Turkewitz & Kenny, 1982). Nevertheless, newborns show a preference for face-like stimuli relative to other types of face-like patterns (Morton & Johnson, 1991), and they also prefer a talking face over a still face (Guellaï, Coulon, & Streri, 2011; Nagy, 2008). It has been

suggested that these early preferences for faces might position the infant to better relate spoken and visual speech (Shaw & Bortfeld, 2015). In the first months of life, infants are very sensitive to visual speech information, since they can discriminate their native language from a non-native solely on the basis of articulatory movements (Weikum et al., 2007). Using a habituation paradigm, Weikum and colleagues (2007) presented 4-, 6-, and 8-month-old monolingual (and bilingual) infants with silent videos of a person talking in their native (English) and a non-native (French) language. The results revealed that 4- and 6-month-olds showed sensitivity to the language switch but 8-month-olds no longer perceived this difference. This decline from 4 to 8 months in perceiving the language switch in the visual domain has been associated with the perceptual attunement to their native language that infants experience in the auditory domain in the second half of the first year.

Furthermore, several studies have shown a developmental shift from eyes to mouth between 3.5 and 12 months in monolingual infants (Hunnus & Geuze, 2004; Lewkowicz & Hansen-Tift, 2012; Tenenbaum, Shah, Sobel, Malle, & Morgan, 2013; Tomalski et al., 2013; Young, Merin, Rogers, & Ozonoff, 2009). It has been suggested that the preference to look to the mouth during the second half of the first year of life reflects more mature linguistic processing of audiovisual speech. Once infants have attained a certain level of language acquisition, they would progressively look back to the eyes, as adults do (Lewkowicz & Hansen-Tift, 2012), likely because the eyes convey an important amount of communicative information.

We will close this review on speech perception by highlighting how social interaction can enhance cognitive processes, in this case, language development. The so-called “social gating” hypothesis was explored by Kuhl (2007) and it is the focus of much ongoing research. As mentioned above, words such as ‘mommy’, ‘daddy’ or the infant’s name are usually the first words that infant recognize (Mandel, et al., 1995; Tincoff & Jusczyk, 1999). These are words that are likely repeated in familiar contexts, so it is possible that direct face-to-face interaction engages the infant’s attention and bootstraps language acquisition.

At the lexical level, recent data show that social cues modulate infants’ attention during word learning and word recognition (e.g., Parise & Csibra, 2012; Baldwin & Moses, 2001; Golinkoff & Hirsh-Pasek, 2006). Likewise, Seidl, Tincoff, Baker, and Cristia (2015) found a direct positive effect of caregiver interaction on finding words in continuous speech. They found that 4-month-old infants could segment

trisyllabic words in an artificial language if during the familiarization period the experimenter touched the infant on one of their body parts at the same time that the infant heard the target word.

At the phonetic level, Kuhl, Tsao, and Liu (2003) investigated whether live-person exposure to a non-native language could foster learning of phonetic information. In their study, three groups of English-learning infants were exposed to Mandarin Chinese in three different situations in several sessions: face-to-face interactions between the native speaker and the infants, videos of the native speaker talking in Mandarin Chinese on TV, or no training. Next, they were tested on the discrimination of a non-native Chinese Mandarin contrast. The results showed that only the group in the face-to-face interactions discriminated the non-native phonetic contrast, similarly to Mandarin Chinese learning infants. Two important findings can be highlighted from this study: first, that although there is a natural decline in sensitivity to non-native contrasts, training can be effective to regain perceptual sensitivity at this age and, second, that social interaction plays a crucial role in language acquisition. More recently, an ERP study has further supported the importance of social interactions in phonetic learning (Conboy, Brooks, Meltzoff, & Kuhl, 2015). In Conboy et al. (2015) study, English-learning infants were exposed to Spanish in several play sessions with a native speaker. The infants who showed higher joint attention with the Spanish-speaking interlocutor during playing sessions at 9.5 months showed stronger ERP responses to a Spanish consonant contrast (/d-t/) at 11 months, indicating that infants' social behaviors may improve phonetic learning. These studies demonstrate that social contexts and communicative exchange may provide relevant information to reverse the perceptual decline in the discrimination of non-native contrasts. Together with the above studies on word-form recognition, these findings reinforce the idea that social cues improve speech encoding, although further studies are needed to explore which specific aspects play a more important role in language acquisition.

To summarize, human infants are born with remarkable linguistic abilities. Indeed, language learning starts in the womb during the last trimester of pregnancy, as revealed by newborns' sensitivity to the prosodic properties of their mother's voice and language. Furthermore, language acquisition involves segmental (phonetic) and suprasegmental (prosodic) information processing. Regarding segmental information, while in the first half of the year, infants can discriminate almost all speech sound

contrasts, in the second half of the first year, they experience a decline in the perception of non-native contrasts, as they become more attuned to the speech sounds of their native language. The timing of perceptual attunement, in turn, corresponds to the age at which infants start being more sensitive to the distributional properties of the sounds of their language. Tracking statistical information is important to detect the possible word forms, or phonotactic patterns of their native language. Regarding suprasegmental information, infants show a preference for the stress patterns of their native language and make use of prosodic cues available in the input to extract words from the speech stream. Lastly, information in communicative contexts such as joint attention, gaze following and social interaction also play an important role in language acquisition, as it can boost vocabulary related abilities and phonetic perception. Before reviewing the literature on language acquisition in the first years of life in children born preterm, it is important to preface our remarks by providing some background to the implications of the transition from the womb to the extrauterine environment.

3.2. Preterm birth: transition from the womb to the extrauterine environment

Up to this point, I have been presenting data about language acquisition in typically developing fullterm infants in a very sensitive period for language acquisition. Indeed, the neonatal period is a critical time of growth of the body organs and development of the neural system (Aylward, 2005). Right after term birth, the developing brain experiences the greatest growth of neurons and synapses. In particular, the rate of synapses formed at this time is faster than at any other period in life. As a result, significant development of cognitive functions occurs. In this context, preterm birth may have negative effects in cortical development and brain connectivity, since it involves the disruption of the typical intrauterine development. This might especially apply to infants born at lower gestational ages for being more immature and vulnerable at the time of birth, positioning them at a higher risk of morbidity, mental and later language problems.

A great deal of work and ongoing debate has focused on the role of biology and experience in development, also known as the nature (&) nurture issue. With respect to children' development, biological factors refer to the genetic component, whereas experiential factors refer to the environment that the children experience in terms of education, affection, or learning, among others. Biological factors affect early

stages of development; however, they do not completely fine-tune the brain. During this early period of development, the brain is most susceptible to the influence of environmental factors. Consequently, the input that the infant receives from the environment also stimulates neural activity, laying the foundation for future development. The question of how environmental circumstances may influence neurophysiological development has been examined, for instance, in monozygotic twins (Holzinger, 1929), in children who have experienced prenatal exposure to alcohol (Lebel et al., 2008), or in adoptive children who suffered from early deprivation (e.g., children raised in impoverished institutions under Romanian dictator Nicolae Ceaușescu's regime; Nelson, 2014). In the latter case of neglected children, researchers have reported severe behavioral problems throughout their lifetime, as well as altered brain structure (Nelson, Bos, Gunnar, & Sonuga-Barke, 2011). Thus, the assumption that events that are under biological control might be altered when the postnatal scenario changes, may apply to preterm birth, since it involves a disruption of the normal neurobiological development along with an unexpected change of the environmental circumstances of the infant. The timing of the experience is crucial to developmental outcome (Nelson et al., 2011), and although the ability to acquire a language is universal (Chomsky, 1965), it is also very experience-dependent (Elman et al, 1996; Karmiloff-Smith, 1998; Piaget, 1961; 1970).

By the time of birth, preterm infants experience different environmental and social circumstances to those of fullterm infants. The intensive care environment is often characterized by noise generated by medical devices around them, which can cause physiological changes in the organism, such as an increase in heart rate, respiratory rate and blood pressure as well as decrease in oxygen saturation (for a review, see Wachman & Lahav, 2010). Furthermore, these circumstances may constrain social interactions between the parents and the infant, limiting the quantity and quality of auditory and audiovisual exposure to language. As a consequence, these multiple changes in the interactions between the immature organism and the sensory stimulations from the extrauterine environment may modulate the neural development of these infants (Karmiloff-Smith, 1998).

Several researchers have highlighted the importance of the timing of sensory stimulation relative to the stage of development. As pointed out by Lickliter (2000), Gottlieb (1968, 1971) proposed that there is a sequential onset of sensory systems function in birds and mammals (tactile → vestibular → chemical → auditory → visual),

resulting in a differential timing of the onset and amount of experience and stimulation of each of these modalities. In other words, by term date, some systems, like the auditory system, have experienced much more stimulation than others, like the visual system, which has had little experience before birth. Building on this idea, Turkewitz and Kenny (1982, 1985) suggested that sensory constraints of some of these systems exist because they allow the immature organism to reduce the amount of information to be processed at a given time and to avoid the competition among them in development. Thus, it is possible that the development of a sensory system is influenced by a) the timing of the stimulation, b) the amount of stimulation provided and, c) the type of stimulation experienced. These three factors may impact neurological organization in the perinatal period (Lickliter, 2000). When preterm birth occurs, the infant's sensory experience changes drastically, disrupts the sequential sensory exposure and may increase competition among the different sensory systems.

Support for these hypotheses comes from various animal studies, suggesting that altered sensory stimulation has an impact on early perceptual, behavioral and neural development. For example, quail chicks exposed to unusual prenatal visual stimulation in the last 24–36h of incubation modify the functioning of auditory perception (Lickliter, 1990). Typically developing quail chicks have a preference for the auditory maternal call, a preference that the early visually stimulated quail chicks did not exhibit when presented only in the auditory modality. However, they did show a preference when presented with both auditory and visual stimuli. Another study on rat pups investigating the effects of early visual experience on homing behavior demonstrated that rat pups exposed to prenatal visual experience relied less on olfactory cues and more on visual cues compared to the typical reliance on olfactory cues (Turkewitz & Kenny, 1985). Thus, it appears that the early exposure to visual information and the competition between the visual (and, in this case, auditory and olfactory systems) influence perceptual learning in non-human species. However, these observations have mainly focused on early stimulation in animals that are not far from their fullterm birth whereas spontaneous preterm birth in humans can occur three months before their due date. The implications of multiple early sensory stimulations on cognitive functions deserve further research. Given that the auditory and visual systems are the last sensory systems to be functional (Gottlieb, 1968, 1971), one way to approach this issue is to focus on a domain that requires mainly auditory and visual input, as is the case of language acquisition.

Regarding the onset of the auditory system and the amount of stimulation, infants who have been born extremely preterm (<28 GWs) have had very short in utero experience with sounds, since the cochlea is only functional by 23–25 GWs (Graven & Browne, 2008). Furthermore, acoustic input has a substantial influence in the development of the auditory system's cellular structure (Moossavi & Panahi, 2017). Whereas a typically developing fetus has had gradual exposure to sounds from lower to higher frequencies, preterm infants do not have the opportunity to gradually develop their tonotopic maps accordingly (Lahav & Skoe, 2014). Hence, not only do they lack experience with the prosodic patterns of their native language, but this early and abrupt change from a protected womb to a high frequency and overstimulating environment may lead to altered/atypical connections between the auditory peripheral system and the auditory cortex. In addition, multiple sensory stimulation (visual, touch, smell, unfiltered sounds), presumably prevents them from isolating auditory input as in the protected womb, increasing processing competition between the different sensory systems (Turkewitz & Kenny, 1982, 1985).

Recent empirical data has addressed the issue of premature birth and its consequences on speech perception mechanisms. Due to their early exposure to unfiltered speech from preterm birth, the study of this population represents an important opportunity among developmental scientists to investigate the relative contribution of postnatal experience and maturational constraints, and their respective timing in the language acquisition trajectory. We will now turn to the factors that influence early language acquisition and the possible effects of premature birth on language development.

As addressed in the previous section, in the early stages of language acquisition, infants are sensitive to the prosodic properties of their native language(s) (rhythm, stress, intonation). The fact that low-pass filtered speech conveys primarily prosodic cues may have several implications regarding language acquisition in preterm infants. If prosodic information provides the foundation for language acquisition (Morgan & Demuth, 1996), it is possible that this first simplified linguistic level bootstraps the acquisition of other language subdomains that require access to high frequencies conveying segmental/phonetic cues (necessary for lexical and syntactic processing). This gradual exposure from low to high frequencies might be important to extract relevant information from the speech at the relevant moment of development. Given that prosodic information is the first source of linguistic input (while phonetic

information mostly becomes available after birth), the question arises as to how deprivation of intra-uterine exposure to speech might affect different aspects of language acquisition and how early exposure to unfiltered speech might modify this process in an immature system. A third possibility is that early postnatal exposure may result in atypical developmental processes (Karmiloff-Smith, 1998; Sansavini, Guarini, & Caselli, 2011). Specifically, the goal of the studies on preterm infants is to investigate the relative role of postnatal linguistic experience and maturation on the acquisition of different language subdomains. In some domains, suprasegmental cues might play a crucial role, while in other domains segmental cues are paramount for acquisition. For example, exposure to suprasegmental information is crucial to discriminate languages with similar rhythmic patterns (Bosch & Sebastián-Gallés, 2001), or the lexical stress of the native language (Höhle et al., 2009). On the other hand, exposure to segmental information is required to learn the possible combinations of phonemes in a given language (Gonzalez-Gomez & Nazzi, 2012b).

Compared to the assessment of language skills at school age, the developmental time course of speech perception in the first year in preterm infants has received attention only recently. To this end, the focus of recent research has begun to shed light on when preterm infants achieve certain early language milestones as earlier predictors of neurodevelopmental outcomes. To evaluate the role of the amount of exposure to broadcast speech from birth onwards, preterm infants are compared with fullterms of the same postnatal age (calculated from the actual date of birth); to evaluate the role of the degree of prematurity (taken as an approximation of maturational status), preterm infants are compared with younger fullterms on the basis of the due date of birth, hence with fullterms of the same term age, often called maturational age as will be done here. Hence, a 6-month-old infant born 3 months before term will be compared with a 6-month-old fullterm (same postnatal age) and a 3-month-old fullterm (same term/maturational age; see Figure 0.2).

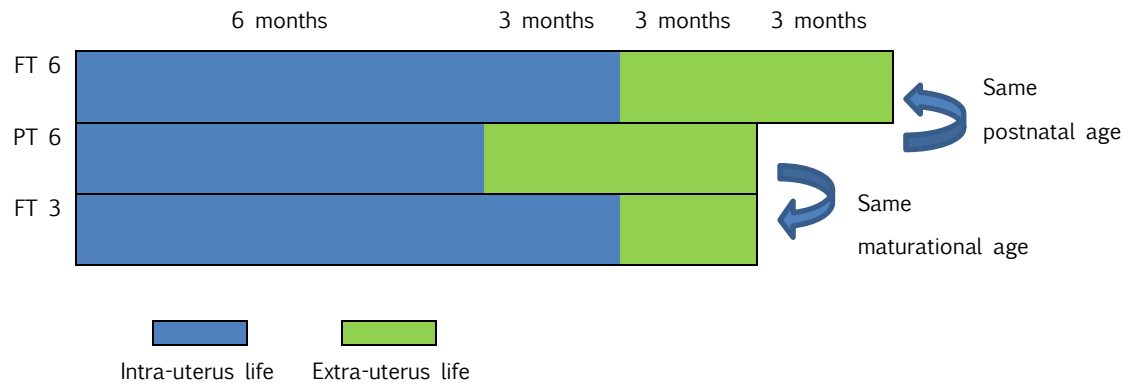


Fig 0.2. Example of a very preterm infant and his/her matching postnatal age peer (i.e. a 6-month-old fullterm; FT6) and maturational age peer (i.e. a 3-month-old fullterm). Duration of intrauterine life is indicated in blue and duration of extrauterine life in green. Adapted from Peña, Pittaluga, and Mehler (2010).

If the attainment of a given language milestone is mostly driven by postnatal experience with speech, then one might expect preterm infants to demonstrate the same ability than fullterm infants at the same postnatal age. However, if exposure to filtered speech supports the acquisition of a milestone or if a certain degree of maturational status is needed to attain it, then preterm infants are expected to achieve it at their maturational age. Lastly, if both experience and maturation contribute to a certain extent to the typical developmental trajectory, teasing apart the contribution of each factor in the cognitive development of preterm infants becomes an even more intricate task.

This issue is highly important given that several studies have reported significant neuropsychological and behavioral deficits at school age in preterm born children even without major neurological problems (Volpe, 1991). In the language domain, preterm children are likely to show speech and language difficulties (Vohr, 2014). Thus, specifying language deficits not only during childhood but also during the first year of life in preterm infants is important given our knowledge of crucial developmental changes and acquisitions in the last trimester of gestation and during the first year of life in fullterm infants (for reviews, see Jusczyk, 1997; Kuhl, 2004).

3.2.1. Preterm infants and language acquisition: Toddlerhood and childhood

3.2.1.1. Standardized tests of language assessment

A significant number of studies have examined language development in children born preterm. The focus of this research ranges from simple to more complex abilities (lexical comprehension and production to syntactic abilities). Although there are many differences among these studies related to the type of measures used, the different linguistic subdomains explored (phonological, lexical, semantic, syntactic, pragmatic), the experimental approach (perception or production) and criteria of sample inclusion (with or without medical complications, degree of prematurity), it appears that premature birth is associated with global linguistic deficits, as reported in reviews and meta-analyses (Barre et al., 2011, Vohr, 2014, Van Noort-Van Der Spek, Franken, & Weisglas-Kuperus, 2011; Guarini, et al., 2016; Guarini & Sansavini, 2011). Indeed, the preterm population is very heterogeneous in nature because it includes infants born at different gestational ages, with different birth weights and varying degrees of medical complications, among other factors. While some studies include children with moderate or severe neurological damage (Pierrat et al., 2017), others only include those who are globally healthy (e.g. Gonzalez-Gomez & Nazzi, 2012a; Peña, Werker, & Dehaene-Lambertz, 2012). This review summarizes the current available literature, highlighting research that has focused on “healthy” preterm children with varying degrees of prematurity during childhood.

From two years on, children born preterm usually show poorer expressive and receptive language when evaluated using traditional methods of language assessment (Wolke & Meyer, 1999; Wolke, Samara, Bracewell, & Marlow, 2008; Stolt et al., 2007; Guarini et al., 2009; Woodward et al., 2009; Foster-Cohen, Friesen, Champion, & Woodward, 2010; Månsson & Stjernqvist, 2014). Identified language deficits in children born preterm include not only lexical comprehension (Caravale, Tozzi, Albino, & Vicari, 2005; Saavalainen et al., 2006), but also lexical production and grammar (Adams-Chapman, Bann, Carter, & Stoll, 2015; Foster-Cohen, Edgin, Champion, & Woodward, 2007; Guarini et al., 2009; Kern & Gayraud, 2007; Saavalainen, 2006; Sansavini et al., 2011; Woodward et al., 2009), as well as phonological awareness (Guarini et al., 2009; D’Odorico, Majorano, Fasolo, Salerni, & Suttora, 2011). It has also been reported that preterm infants exhibit poorer verbal working memory (Aarnoudse-Moens, Duivenvoorden, Weisglas-Kuperus, Van Goudoever, & Oosterlaan, 2012), and that

decreasing working memory in this population is associated to poorer language outcomes (Caravale, Tozzi, Albino, & Vicari, 2005). Importantly, differences between preterm and fullterm children get bigger as language increases in complexity (van Noort-van der Spek et al., 2011).

Most of these studies have focused on children born extremely and very preterm because they are the most vulnerable children. Less attention has been paid to children born moderate and late preterm, given the belief that, being born just a few weeks early, their outcomes would not differ substantially from fullterm children. Yet, recently, several studies have shown that moderate and late preterm infants have a higher incidence of neonatal medical complications than their fullterm peers, as well as more negative long term outcomes in terms of health, neurodevelopment or education (for a review see Boyle & Boyle, 2011). Stene-Larsen and colleagues (2014) found that children born late preterm are at risk of communication impairments between 18 and 36 months. At school age, several studies have found poorer academic performance in children born between 32 and 36 GWs than in fullterm children, highlighting the need for follow-up and intervention programs in these children (Chyi, Lee, Hintz, Gould, & Sutcliffe, 2008; Quigley et al., 2012; for meta-analyses on moderate and late preterm children, see McGowan, Alderdice, Holmes, & Johnston, 2011; De Jong, Verhoeven, & van Baar, 2012). Consequently, increasing evidence suggests that this subgroup of preterm children is also at risk of developmental outcomes and academic difficulties, and that there is a need to further investigate their developmental trajectory of language acquisition.

An increasing number of studies have aimed to explore the link between gestational age and birth weight, along with the risk for medical complications, and how all these factors modulate linguistic outcomes in different subgroups of preterm infants during childhood. In general, these studies have found greater delays for extremely and very preterm children than for moderate and late preterm children. Foster-Cohen et al. (2007) studied extremely (<28 GWs) and very preterm (28>32 GWs) infants' word comprehension, and production and sentence comprehension, by 24 months. The group of extremely preterm infants scored significantly lower than the very preterm group on the MacArthur-Bates Communicative Development Inventory (Fenson et al., 2007) and both groups performed significantly below fullterm children. In a study of over 300 preterm participants, children born moderate and late preterm did not differ in lexical and grammatical performance from fullterm children at the age of 2,

although those born extremely preterm and, to a lesser extent, those born very preterm, obtained lower scores than their fullterm peers (Gayraud & Kern, 2007; for similar results see Sansavini, Guarini, Alessandroni, Faldella et al., 2006). However, in another study testing over 700 children at different points in their development (20 months, 3 and 6 years of age), children born moderate and late preterm had lower scores in language assessments than fullterm children, but higher scores than children born very preterm (Putnick, Bornstein, Eryigit-Madzwamuse, & Wolke, 2017; for a review of language outcomes of children born before 37 GWs between 3-12 years, see van Noort-van der Spek et al., 2011). Therefore, these studies establish language deficits in the different subgroups of preterm children in the first years of life that are at least partly modulated by degree of prematurity, and may persist into the school years, affecting their academic performance (Pritchard et al., 2009; Lee, Yeatman, Luna, & Feldman, 2011; Sansavini, et al., 2011; Wolke, Samara, Bracewell, Marlow & EPICure Study Group, 2008).

3.2.1.2. Experimental studies

In the last fifteen years, researchers have started to characterize language processing by using fMRI to better understand the recruitment of neural systems engaged by different linguistic tasks and compare them to behavioral outcomes (Peterson et al. 2002; Wilke, Hauser, Krägeloh-Mann, & Lidzba, 2014; Myers et al. 2010). Given that previous studies had revealed that preterm infants display structural and connectivity differences with respect to infants born at term (Constable et al., 2013), and that these differences range from the newborn period until adolescence (Anjari et al., 2009; Dubois et al., 2008; Gimenez et al., 2008), brain imaging techniques may provide better insights on the impact of premature birth on linguistic and cognitive processing.

By identifying what regions activate during a particular task, further evidence can be provided on the engagement of same or alternative neural systems in the developing preterm brain. For instance, Reidy et al. (2013) found that neonatal white matter abnormalities were negatively correlated with phonological awareness and, to a lesser extent, to semantics, grammar, and discourse on a standardized language test. Peterson et al. (2002) noted that former preterm infants at 8 years, exhibited a pattern of brain activity during semantic processing similar to the pattern of brain activity displayed by controls for phonetic processing, indicating that semantic processing is

altered. Furthermore, alterations in this neural network were associated to lower verbal IQ scores in the group of preterm children. Similarly, another study found that these differences between very preterm and fullterm children in neural activation during language tasks may last until adolescence (Barde, Yeatman, Lee, Glover, & Feldman, 2012). Taken together, these studies point to the presence of an alternative language organization in preterm children (especially in very preterm) and call for a better understanding of the relationship between neural activation, connectivity patterns and brain abnormalities associated to preterm birth.

To the best of our knowledge, few studies have investigated preterm language acquisition during the second year of life. Infants start detecting the first familiar words in the first year, but it is during the second year their word recognition abilities continue to increase. This improvement might be coupled with production skills, as evidenced by the vocabulary spurt that children undergo between 18-20 months of age (Goldfield & Reznick, 1990). Furthermore, infants' production inventory has been found to be related to early word perception (DePaolis, Vihman, & Keren-Portnoy, 2011), which underscores the importance of studying early word comprehension and production in both typical and at-risk populations.

One of the paradigms that has been used in typically developing infants to study the first stages of word recognition is the looking-while-listening paradigm (LWL) (Fernald, Zangl, Portillo, & Marchman, 2008). This paradigm allows tracking infants' gaze patterns while they look at pictures of different objects and listen to speech naming a familiar object. Recently, Marchman, Adams, Loi, Fernald, & Feldman (2016) used this paradigm in very preterm infants at 18 months of maturational age to examine whether efficient early recognition of familiar words and online language processing was related to later receptive vocabulary at 36 months. It is worth highlighting two main results: first, that the preterm group generally looked to the target picture above chance levels (60%), and second, that processing efficiency (reaction time and accuracy) at 18 months was associated to higher vocabulary scores at 36 months. As to where this variability in reaction time might come from, the authors suggest the possibility that if the study had included a larger group ($n=30$), factors including gestational age, birth weight, and medical risk might have been found to account for processing speech measures and/or later vocabulary skills. Previous studies had revealed that individual differences in word recognition speed predict later language outcomes in fullterm toddlers (Fernald, Perfors, & Marchman, 2006; Fernald & Marchman, 2012). This study

constitutes, therefore, an important contribution by tapping onto speed information processing as a measure linked to later language outcomes in preterm children. In a similar study (Loi, Marchman, Fernald, & Feldman, 2017), preterm children's performance on the LWL word recognition task at 18 months was similar to that of the group of fullterm toddlers matched on maturational age rather than on postnatal age. The preterm toddlers, in contrast, performed below both groups of fullterm children in the standardized measures of language.

In fact, this LWL paradigm had been previously used by Ramon-Casas, Bosch, Iriondo, and Krauel (2013) in very preterm infants at a slightly later age, at two years maturational age, an age at which fullterm infants reliably associate familiar words to objects. The group of preterm infants recognized the familiar words with similar accuracy as controls. However, significant differences were found between both groups in processing speed measures (longest look duration, number of changes in fixation per trial –an indicator of exploratory behavior–, and latency to switch from the distracter), establishing poorer performance of preterm infants. In this study, there was a relation between birth weight and accuracy in this task, and a marginal effect for gestational age (but no effect of medical risk). To our knowledge, this work was the first to use online measures of lexical processing and indicates, once again, the importance of gestational age and birth weight to account for variability in preterm linguistic performance.

In sum, even though most of the literature converges on the fact that preterm children present deficits in linguistic outcomes, the current state of knowledge about the early effect of prematurity on acquisition during infancy is still limited. In the next section, we will review the studies that have investigated the effect of prematurity in language acquisition in the first year of life.

3.2.2. Preterm infants and language acquisition: Infancy

The question that remains largely unanswered is how prematurity might affect different language subdomains, especially in the first year of life. Studies on preterm infants provide a unique opportunity to study the role of maturation and postnatal experience in language development. Because infants' speech perception abilities undergo a gradual improvement in native speech perception and a decline in non-native speech perception in the first year of life, this period provides an optimal window to explore this effect. On the other hand, we must be cautious about the

scope of the findings with respect to prematurity, since these studies explore predominantly language abilities in healthy preterm children. It is important to understand these limitations when interpreting these studies. In the following section, I will review the main contributions on language acquisition in preterm infants based on the last fifteen years of research. This research has brought about a better understanding of how maturational constraints and postnatal experience with broadcast speech shape speech perception abilities.

3.2.2.1. Prosodic/Suprasegmental information

Suprasegmental cues are relevant in language acquisition because they convey lexical stress, intonation or rhythmic information. Prosodic information supports identification of lexical items or syntactic relationships that are language dependent. Infants gradually increase their speech perception abilities in the native language allowing them to become native listeners and speakers (Gervain, 2015). Because infants are sensitive to prosodic information prenatally, preterms' reduced exposure to this dimension might affect certain linguistic skills that require prosodic processing in preterm infants.

One of the first topics of investigation has been the recognition of the maternal voice. Therien and colleagues (2004) explored maternal voice recognition in very preterm infants at the term-equivalent age in an ERP study. They were first familiarized with 60 trials of the maternal voice followed by a test phase in which the maternal voice alternated at random intervals with a stranger's voice. Preterm infants showed no difference ERP response between the mother's and the stranger's voice whereas fullterm infants showed evidence of response to the stranger's voice over the entire scalp. The absence of response in the preterm group could be explained by insufficient exposure to the maternal voice in utero. Likewise, deRegnier and colleagues (2002) investigated the effects of maturity and postnatal experience with speech in the recognition of the maternal voice in three groups of infants: a) a group of late preterm infants tested during the first 7 days of life, b) a fullterm group, tested during the first 7 days of life, c) A fullterm group, tested between 8-30 days. Infants were presented with the maternal voice (i.e. repetitions of the word 'baby') and a stranger's voice pronouncing the same word. While the group of late preterm infants showed no evidence of recognition of maternal voice, both groups of fullterm infants showed a response.

Second, several studies have explored stress pattern processing in preterm and fullterm infants. Cross-linguistic data on fullterm infants from syllable- and stress-timed languages has shown that infants discriminate trochaic and iambic patterns at 4 and 6 months, and infants learning a stress-timed language show a preference for the lexical stress pattern of their native language at 6 months (Herold, et al., 2008; Höhle, et al., 2009). Hence, these studies demonstrate that the trochaic bias is language-specific and that stress discrimination becomes language specific in stress-timed languages by 4-6 months. Crucially, less efficient discrimination abilities between the trochaic and iambic stress patterns at 4 months in German-learning infants have been associated to lower word production scores at 12 and 24 months (Weber, Hahne, Friedrich, & Friederici, 2004) and to lower language performance at 5 years of age (Höhle, Pauen, Hesse, & Weissenborn, 2014). The existence of these correlations highlights the importance of detecting early impaired or delayed prosodic processing as possible indicators of subsequent language deficits observed in preterm children.

The first study on word stress pattern discrimination in German-learning very preterm infants was conducted by Herold and colleagues (2008) using the head-turn preference (HPP) procedure. First, a 4-month-old fullterm group and a 4-month-old maturational age preterm group were familiarized for 30 seconds with a trochaic bisyllabic sequence, and then presented with iambic and trochaic sequences. In contrast to the fullterm group, preterm infants did not show discrimination of the trochaic and iambic patterns. In a second experiment, a group of 6-month-old fullterm infants and preterm infants at 6 months maturational age were tested on their preference for the trochaic pattern. In this experimental session, there was no familiarization; infants were directly presented with the iambic and trochaic sequences. The control group preferred the trochaic pattern, while no preference was observed in the preterm group. The authors argue that prosodic sensitivity in preterms may be delayed or impaired in the first half of the year due to the lack of intra-uterine speech exposure and the closed-wall incubator nursing.

In order to test the hypothesis that intra- and extra-uterine development could differently affect suprasegmental and segmental information processing abilities (Gonzalez-Gomez & Nazzi, 2012a), Ragó, Honbolygó, Róna, Beke, and Csépe (2014) used an experimental design that allowed for comparison of word-stress processing and phonetic information in Hungarian, another stress-timed language with a highly regular lexical stress pattern. Four groups were tested in total: a group of 6-month-old

fullterms; a group of 6-month-old postnatal age preterm infants (from 28 to 36 GWs; mean = 31.8 GWs); a group of 10-month-old fullterms; and a group of 10-month-old postnatal age preterm infants (from 28 to 33 GWs; mean = 30.6 GWs). An oddball paradigm was used to measure mismatch negativity responses. The standard stimulus was the word 'banán' (Hungarian word for 'banana'), and the two deviant stimuli were phoneme-deviant 'panán' (a nonword) and stress-deviant 'ban:án', which was stressed on the second syllable instead of on the first one, as is usual in Hungarian. No differences were found between the fullterm and preterm groups for the phoneme-deviant condition with all four groups showing significant mismatch negativity (MMN) responses. In contrast, differences were observed between the preterm and fullterm groups in the stress-deviant condition, with preterm infants showing a more attenuated response than fullterms (Ragó, et al., 2014). These results, together with the findings on lack of prosodic preference and discrimination from Herold et al. (2008), suggest that prematurity affects prosodic acquisition at the lexical level. Would it also affect prosodic at a different level, such as the early ability to discriminate different languages?

Recall that newborns can discriminate languages that belong to different rhythmic classes (Nazzi et al., 1998), probably thanks to the language general sensitivity to rhythmic differences. But it is not until 4 months that they discriminate two rhythmically similar languages (Bosch & Sebastián-Gallés, 2001; Nazzi, et al., 2000). By measuring visual orientation times, Bosch (2011) found evidence of discrimination of two rhythmically-different languages (Catalan or Spanish vs. English) in preterm infants at 4 months maturational age, effect also found in the control group. However, the preterm group showed slightly longer latencies to the native language compared to the control group which, as pointed out by the author, could reflect slower information processing. In a more challenging task which consisted in discriminating rhythmically-similar languages (Spanish versus Catalan) at 6 months maturational age, preterm infants showed successful discrimination, the same response pattern as the control group. A possible explanation for the differences found between Herold et al. (2008) and Bosch (2011) is that, whereas the former focuses on a specific word stress pattern, the latter requires a more general recognition of the ambient language, which might require less cognitive effort.

Bosch's (2011) findings are further supported by a similar study from Peña, Pittaluga, and Mehler (2010), testing discrimination of rhythmically-similar languages in

very preterm infants at 6 and 9 months postnatal age and in fullterm infants at 3 and 6 months of age. Brain activity was recorded using electroencephalography (EEG) while infants listened passively to utterances in their native language (Spanish), a rhythmically-similar language (Italian) and a rhythmically-different language (Japanese). This design allowed a direct comparison of preterm infants' responses to their fullterm peers matched on maturational age or on postnatal experience. The responses (gamma-band oscillations) of the fullterm infants showed that 6-month-olds (but not 3-month-olds) discriminated between Spanish and Italian. Preterm infants showed discrimination at 9 months postnatal age but not at 6 months, suggesting that maturational status better reflects discrimination abilities for rhythmically-similar languages. However, at 9 months of postnatal age, preterm infants have gained not only in maturation, but also in exposure to the prosodic features of their native language (which fullterms have had access to during the last trimester of pregnancy).

In short, the above studies point to early differences in sensitivity to lexical stress and rhythmic properties between fullterm and preterm infants. Maturational status and lack of intra-uterine exposure to speech could partly explain the prosodic delays found in preterm infants (i.e. delay in terms of attaining a skill at the maturational age or later). This could subsequently have cascading effects on the acquisition of later language milestones. However, early exposure to broadcast speech may not equally impact all linguistic levels. In the next section, we turn to research investigating language perception skills related to segmental information.

3.2.2.2. Phonetic/Segmental information

Recent studies have aimed at understanding the influence of extrauterine development in an immature brain without major neurological problems in order to assess whether phonetic processing can be modified as a consequence of early auditory (and other sensory) exposure. In contrast with suprasegmental information, segmental information (mainly high frequency sounds) is only available after birth. According to the hypothesis put forward by Gonzalez-Gomez and Nazzi (2012b), the acquisition of language subdomains that do not require prenatal speech exposure might not be affected in the same way as other domains in which prosodic cues are paramount. This is the case, for instance, of consonantal features that are distinguished based on high frequency information. In the following paragraphs, I will

describe studies that have documented differential responsiveness to segmental cues during the first year.

A recent study by Mahmoudzadeh et al. (2013) investigated phoneme discrimination in syllables (e.g. /ba/ vs /ga/) and detection of human voice change in very preterm infants tested between 28 and 32 GWs using near-infrared spectroscopy (NIRS). The results showed that the left frontal region reacted to a phoneme change, and that the contralateral right frontal region reacted to both a change of phoneme and voice. The authors suggest that this asymmetry indicates early hemispheric differentiation in humans. The second implication of their results showing sensitivity to changes in phonemes and voices is that the immature human brain can process linguistic stimuli from very early in development.

While the previous study investigated speech perception before preterm infants attain the term age, other studies at term-equivalent age have found contrasting results. Unlike fNIRS, recording ERPs allows for better temporal resolution, providing more details about the speed and efficiency of brain processing. A few studies have used ERPs to detect the effects of preterm birth on speech processing. Very preterm infants with no brain abnormalities have been found to show atypical response patterns to the detection and discrimination of phonemes at term equivalent age (Therien et al., 2004). The test consisted in a phoneme change task, in which infants were presented 88% of the time with one syllable (e.g. /bi/), while in 12% of the time, the consonant of the syllable was replaced (e.g. /gi/). Although both groups discriminated the two sounds, preterm infants showed differences in polarity with respect to fullterm infants. Moreover, the preterm group presented lower peak amplitudes in discrimination response than the fullterm group, suggesting that maturational constraints support speech perception. In line with this maturational constraint, Key, Lambert, Aschner, and Maitre (2012) found greater ERP amplitude differences for consonant differentiation as gestational age and postnatal age increased in the first 4 months after birth. Interestingly, these authors also found that infants born at low gestational ages (<30 GWs) did not show the same increase in ERP amplitude with increasing postnatal age as preterm infants born later (>30 GWs), suggesting that very and moderate preterm infants might follow different developmental patterns. Taken together, these results indicate that some early auditory discrimination abilities are in place at birth, while more research will make it possible to elucidate the differential speech processing

patterns between preterms and fullterms tested at the same gestational age even in the absence of major brain abnormalities.

It must be acknowledged that the period right after birth and until reaching the term equivalent age is a time when preterm infants are more vulnerable to medical complications (and much remains unknown about how this state affects speech perception). While the above studies provide valuable information regarding the specialization of the cortical network in speech processing in the neonatal period, another line of research examined the effect of maturational and postnatal age on phonetic speech perception later in the first year of life to provide crucial insights into the relative role of these factors on phonological acquisition.

As research over the last few decades has demonstrated, infants quickly tune into the language-specific properties of their native language. Several studies have investigated whether preterm infants present similar sensitivities to native and non-native phonetic features. Regarding native contrasts, Figueras Montiu and Bosch Galceran (2010) assessed discrimination of a native vocalic contrast in 4-month-old fullterm and very preterm infants at 4 months of maturational age. Very preterm infants failed to discriminate the vocalic contrast (/dodi-/ /dudi/) while fullterm infants showed successful discrimination (Figueras Montiu & Bosch Galceran, 2010). However, note that in Ragó et al.'s (2014) study, preterm infants at 6 months of postnatal age detected a consonant contrast present in their native language (/banan-/ /panan/), similarly to 6-month-old fullterms despite their different maturational status (Ragó et al., 2014). Perhaps the discrepancy in results can be attributed to differences in the range of gestational ages included: while in Figueras Montiu and Bosch Galceran (2010) all participants were very preterm infants, Ragó et al. (2014) included infants born between 28-36 GWs. Another possibility is that the contrasting findings are related to cross-linguistic differences (Spanish/Catalan versus Hungarian), acoustic saliences (vowels versus consonants) and stimuli differences (e.g. different talkers versus one talker).

Regarding non-native phonetic features, the ability to perceive non-native contrasts declines between 6 and 12 months of age in fullterm infants (Werker & Tees, 1984). Assessing the degree to which preterm infants remain open to non-native speech sounds may signal slower language learning (Kuhl, 2004) and could be used as a predictor of delayed first language acquisition. For example, Peña and colleagues (2012) documented that very preterm infants stop displaying an ERP response to a

non-native consonant contrast (dental /da/–retroflex /Da/) at around 15 months postnatal age, 3 months after fullterms, suggesting a delay in phonological acquisition (Peña et al., 2012). This is important given previous research revealing that the earlier children fail to notice a non-native phonetic difference, the better their later language development (Kuhl et al., 2008).

Besides phonemes, infants are sensitive to native language phonotactics. For fullterm infants, it has been found that some of phonotactic patterns are learned by 9–10 months (refs English: Jusczyk, & Luce, 1994; French: Nazzi, Bijeljac-Babic, Bertoni, 2009; Gonzalez-Gomez & Nazzi, 2012b). The possibility that the acquisition of phonotactic patterns is based on duration of listening experience was addressed in Gonzalez-Gomez and Nazzi's (2012a) study by comparing preterm infants at 10 months postnatal age to two groups of fullterm infants matched on postnatal age (10 months) or maturational age (7 months). Preterm infants were at the same level as fullterm 10-month-olds, preferring a labial–coronal (e.g. bat) over a coronal–labial (e.g., tap) pattern. No preference was found in 7-month-olds, demonstrating that the lack of prenatal exposure to speech did not affect the emergence of the consonantal labial–coronal perceptual bias and that its acquisition was rather based on the duration of input experience (Gonzalez-Gomez & Nazzi, 2012a).

3.2.2.3. Word-related abilities

3.2.2.3.1. Segmentation

Recent research investigating other language domains more directly linked with word learning has focused on preterm infants' ability to extract word forms from fluent speech and on the sensitivity to word-object relations. As previously described, fullterm infants start segmenting word forms between 6 and 8 months of age in different languages (English: Jusczyk & Aslin, 1995; Jusczyk, et al., 1999; German: Höhle & Weissenborn, 2003; French: Goyet, et al. 2013; Nazzi, et al., 2014; Nishibayashi, et al., 2015; Spanish and Catalan: Bosch, et al., 2013). Furthermore, the ability to find word forms in fluent speech has been associated to higher vocabulary levels at two years (Junge, Koijman, Hagoort, & Cutler, 2012; Kooijman, Junge, Johnson, Hagoort, & Cutler, 2013). This skill started to be explored recently in preterm infants. Bosch (2011) conducted a segmentation study in very preterm infants acquiring a syllable-timed language (Spanish or Catalan). Using HPP, a group of very preterm infants at 8 months of maturational age and a group of fullterm 8-month-old infants were familiarized with

two passages (45 seconds each) containing a target monosyllabic word (CVC or CVCC words). Then, in the test phase, they were exposed to two familiar words or two novel monosyllabic words. While no differences were found between the preterm and fullterm groups in the attention measures during familiarization (similar number of trials and similar decline from first to last trial), only the fullterm group showed a segmentation effect (novelty effect), suggesting that the task of extracting the word from the passage, retaining it and matching it during the test phase, might require cognitive demands too high for preterm infants.

Segmentation abilities, however, have recently been found in preterm infants during the first year. In an ERP study, Kabdebon, Peña, Buiatti, & Dehaene-Lambertz (2015) tested whether preterm and fullterm infants were able to detect non-adjacent statistical information (a systematic dependency between the first and the third syllable of pseudowords separated by no prosodic cue except a subliminal 25ms pause between words) in fluent speech and demonstrate subsequent recognition of word units presented in isolation. Two groups of preterm infants were tested (a group of 8 months of maturational age and a group of 8 months of postnatal age), along with a group of 8-month-old fullterm infants. After being familiarized for 190 seconds, the infants heard isolated rule-words or part-words. The results demonstrated that, regardless of the group, all infants were sensitive to the trisyllabic sequences, as revealed by an increase in phase locking value, and to the difference between rule-words and part-words during the test phase. Given that no group differences were found between the three groups, this study establishes that preterm infants having a postnatal experience of 8 months are capable of computing non-adjacent dependencies to segment fluent speech.

Kabdebon et al.'s (2015) findings contrast with Bosch's (2011) results, although the different results could be explained by several factors, including the type of measure used (behavioral = overt behavior versus electrophysiological = passive listening), or the type of stimuli (prosodic cues versus nonprosodic cues). As reviewed at the beginning of this section, when prosodic cues are relevant for the task, preterm infants need to attain the maturational age (e.g. for discriminating different languages). Thus, in the absence of prosodic cues, it is possible that preterm infants rely on other information, such as statistical cues (only available after birth), facilitating the acquisition of what a good candidate word is.

3.2.2.3.2.Comprehension

One mechanism thought to enable vocabulary acquisition is the ability to associate a word to a physical object. Caregiver communication provides many opportunities to name an object at the same time as the person moves it or looks at it. This synchronous intersensory information highlights word-object relations across the auditory and visual modality (Gogate & Hollich, 2010). Studies on fullterm infants on the perception of word-object mappings in the presence of synchronous events has shown that 2-month-old infants are sensitive to changes in temporal relations between syllable-object pairings following habituation to a synchronous syllable-object pairing.

In a subsequent study, Gogate, Maganti, and Perenyi (2014) compared a group of 2-month-old fullterm infants with two groups of moderate and late preterm infants (32-36 GWs) at 2 months of postnatal and of maturational age. The goal of the study was to shed light on whether the development of the ability to make new (synchronously presented) syllable-object links driven by environmental experience (postnatal age) or by maturational status (maturational age). Several differences were found between both preterm groups and the fullterm group. At 2 months of postnatal age, preterm infants showed shorter habituation duration than fullterm infants and no visual recovery to either the syllable or the object change during the test phase, compared to the fullterm group. At 2 months of maturational age, although duration of attention during habituation increased with respect to the postnatal age group, visual recovery to either syllable or object was still not significant, suggesting that neurosensory systems might be partly compromised even after correction for prematurity. It must be noted that the participants in this study were moderate and late preterm infants who tend to experience shorter hospital stays than very preterm infants, and have more opportunities for face to face interactions with their caregivers. However, they still showed attenuated sensitivity to synchrony between a syllable and an object pairing. The early deficit found in the ability to map a syllable and an object might have cascading effects in later word acquisition abilities and subsequent vocabulary development.

Another subdomain that requires visual and auditory processing to develop language-related cognitive functions is the ability to form object categories. Some studies have revealed that, by 3 months of age, when infants have been presented with different images belonging to the same category (e.g., dinosaurs) presented in conjunction with a sentence naming the target, they form an object category as

demonstrated by different looking times to another object of the same category versus an object of a new category. Why is it language-related? Because, interestingly, infants only form object categories in this task if they also listen to language, and not to other types of sounds, such as sine-wave tones (Balaban & Waxman, 1997; Ferry, Hespos, & Waxman, 2010; Fulkerson & Waxman, 2007). Preterm infants exhibit a developmental shift from familiarity to novelty preference as fullterm infants at the maturational age, but not at the postnatal age (Perszyk, Ferguson, & Waxman, 2016), suggesting that maturational status better explains the developmental trajectory observed in fullterm infants when linking objects and language sounds. Additionally, the importance of studying this ability in preterm infants is supported by evidence found in the second year of life, in particular by the fact that infants with a more precise ability to link labels and categories at 12 months have better receptive vocabulary at 18 months (Ferguson, Havy, & Waxman, 2015). It would be interesting in future longitudinal studies to test this ability at 12 months in preterm infants to better understand the links between labelling, object categorization, and receptive vocabulary.

3.2.2.3. Face-to-face interactions

Nevertheless, additional research on gaze following in preterm infants (Peña et al., 2014) has reported similar abilities to fullterm infants at the same postnatal age. The ability to follow an adult's gaze toward a toy when cued either by head and eye movement or only by eye movement was found at 7 months postnatal age in preterm infants, similarly to 7-month-old fullterm and unlike 4-month-old fullterm infants (Peña, Arias, & Dehaene-Lambertz, 2014). Certainly, the few findings exploring audiovisual speech processing in preterm infants are not enough to resolve the question of why some abilities are present at the postnatal or maturational age, whereas children born preterm encounter language difficulties throughout toddlerhood and childhood.

3.2.2.4. Conclusion

Taken together, these recent findings indicate that preterm infants' speech perception abilities during the first year cannot be categorically linked to postnatal or maturational status. Rather, it seems that their performance depends on the type of experience (e.g. experience with prosody, experience with high frequency sounds) and the type of cue (e.g. segmental, suprasegmental, social, visual, audiovisual) that might be more relevant for the early acquisitions in each linguistic subdomain.

4. Objective of the present thesis

Given the few studies on early language acquisition in preterm infants and the lack of a clear developmental trajectory, the present work sought to contribute to further understand early speech perception abilities in this population. It examined the effects of postnatal age (hence, early sensory stimulation) on the developing preterm infants' ability to achieve certain milestones during the first two years of life. Furthermore, it explored the effect of the degree of prematurity on linguistic performance by including extremely-to-late preterm infants. In light of what we know on typically developing infants, the present study sought to compare preterm and fullterm infants': a) early segmentation abilities (Chapter 1: Experiments 1-5); b) audiovisual speech processing of a talking face (Chapter 2: Experiment 6); and c) word recognition and vocabulary production (Chapter 3: Experiments 7-8).

The aim of the following studies was to explore when and how preterm infants perceive speech in the first two years of life. All experiments used behavioral measures: the Head-turn preference procedure in Chapters 1 and 3; eye-tracking in Chapter 2.

Chapter 1 explored segmentation abilities in preterm and fullterm infants. Experiment 1 investigated monosyllabic word segmentation in monolingual French-learning preterm infants at 6 months of postnatal age, as such ability had been previously found in fullterm 6-month-old French-learning infants. Since segmentation abilities have been related to later word learning in fullterm infants (Junge et al., 2012; Kooijman et al., 2013), it is relevant to explore whether these abilities are in place in preterm infants. Experiment 2 tested whether this ability could be found in younger fullterm infants, testing 4-month-olds. By testing these two groups, the study aimed at investigating segmentation abilities in preterm infants, and at better specifying the developmental trajectory (emergence) of these abilities in fullterm infants. In Experiment 3, monolingual French-learning preterm infants at 6 months of postnatal age were tested on the ability to segment a syllabic unit embedded in a bisyllabic word, an ability previously found in fullterm 6-month-olds, in order to determine whether preterm infants use the rhythmic unit of French to segment speech.

In Experiment 4, preterm infants at 8 months of postnatal age were tested in a segmentation test that aimed at exploring the emergence of the consonant bias. Between 6 and 8 months, fullterm infants shift from a vowel to a consonant bias when processing word-forms in a word segmentation task (Nishibayashi & Nazzi, 2016). If experience with consonants (perceived after birth) is crucial for the emergence of this

bias, it is plausible that preterm infants will also show a consonant bias at 8 months of postnatal age.

In the last experiment of Chapter 1 (Experiment 5), bilingual preterm and fullterm infants at 6 months (postnatal age for the preterm group) participated in the same monosyllabic word segmentation task as in Experiment 1-2. The goal was to investigate whether bilingualism has an effect in word segmentation abilities in both populations. Based on the idea that, from birth, newborns prefer syllables over other speech units (Bertoncini, Bijeljac-Babic, Jusczyk, Kennedy, & Mehler, 1988), the hypothesis tested here is whether bilingual infants of French and another language (either also syllable-timed or not) are able to segment monosyllabic words from fluent speech at the same age as reported for their monolingual peers.

In Chapter 2, Experiment 6 explored audiovisual speech processing of a talking face in fullterms and preterms by comparing visual scanning patterns to both native and non-native speech in three groups of infants: preterms of 8 months of postnatal age and fullterms matched at the same postnatal and maturational age. Based on the studies on social cognition and detection of audiovisual fluent speech perception revealing deficits in preterm infants, we hypothesized that preterm birth would be associated with a delay or an alteration in audiovisual speech perception.

Lastly, in Chapter 3, Experiment 7 investigated auditory recognition of familiar words in monolingual French-learning preterm infants at 11 months of postnatal age, ability previously found at the same age in their fullterm peers. Finally, Experiment 8 explored the appropriateness of using postnatal age or maturational age in the assessment of vocabulary production at the age of 24 months.

Due to recruitment constraints, complete neonatal information for all participants was only available for Experiments 1 and 2 (article accepted in *Infancy*). However, for all experiments, the experimenter verified through parental report and the child health booklet that the children included were in a “healthy” condition and that no major health problems were reported.

The interest of this work in particular, and of research on language acquisition in preterm infants, is not only to discover the developmental trajectory (typical, delayed or atypical) of preterm infants from a theoretical point of view, but also to promote future intervention when possible. Discovering the factors that play an important role in early speech perception processes in this population is necessary to understand the

origins of the higher risks of encountering developmental problems found in this population.

CHAPTER 1. Early segmentation abilities in preterm infants

The present chapter explores the emergence of basic segmentation abilities in preterm and fullterm infants and the emergence of a consonant-bias in preterm French-learning infants. Investigating segmentation abilities in preterm infants is crucial because this ability is related to later lexical development. Since preterm children show lower performance in lexical receptive and productive abilities at two years in standardized tests, difficulties segmenting speech might be detected during the first year. On the other hand, they might be able to segment very basic units but encounter more difficulties when cognitive demands increase.

We conducted five experiments testing monosyllabic word segmentation in monolingual preterm infants and fullterm infants. Experiment 1 investigates segmentation of monosyllabic at 6 months of postnatal age and Experiment 2 explores the emergence of this ability in 4-month-old fullterm infants. Experiment 3 tested monolingual preterm infants at 6 months of postnatal age on the ability to segment a syllabic unit embedded in a bisyllabic word previously found in fullterm 6-month-olds. Experiment 4 explored the emergence of the consonant bias in 8-month-old preterm infants using a segmentation task, as previously reported in 8-month-old fullterm infants (Nishibayashi & Nazzi, 2016). Finally, Experiment 5 explored segmentation of monosyllabic words in bilingual preterm and fullterm infants to investigate whether this ability emerges at the same age as in their monolingual peers.

Pages 54-73 contain the article:

Berdasco-Muñoz, E., Nishibayashi, L. L., Baud, O., Biran, V., & Nazzi, T. (2017). Early Segmentation Abilities in Preterm Infants. *Infancy*.

Non-published follow-up experiments

3. Experiment 3. Embedded syllables: Preterm infants at 6 months

Given that, in the previous experiments, the words to be segmented corresponded to the syllabic unit, which is a privileged processing unit in newborns and young infants (Bertoncini et al., 1988) and is also the rhythmic unit of French. Therefore, it is possible that segmenting monosyllabic words from the speech stream presents some advantages for young French-learning infants. The speech signal contains prosodic boundaries, characterized by changes in the speech rate that can signal linguistic constituents. For instance, newborns can discriminate bisyllabic sequences (e.g. mati) that belong to an embedded word (e.g. as in mathématicien) from sequences spanning over two words (e.g. as in panorama typique; Christophe, et al., 1994; Christophe, et al., 2001). Thus, segmenting a syllable embedded in a larger word may present an additional difficulty for the infant, since it leaves less prosodic cues available in the acoustic signal when the syllable does not correspond to the word unit. Previous work carried out in our laboratory by Nishibayashi et al. (2015) tested the hypothesis that French-learning infants use the syllabic unit as a segmentation cue by familiarizing them with passages in which the same syllable was embedded in different bisyllabic words and testing them on the familiar and control syllable in isolation. The results showed that 6-month-old French-learning fullterm infants were able to segment the embedded syllable after extending the familiarization time to each passage from 30 to 45 seconds (Nishibayashi et al., 2015). Following these findings, Experiment 3 continues to assess segmentation of the syllabic unit in preterm infants in, by exploring how they segment embedded syllables in bisyllabic words.

Why is it interesting to assess this ability in preterm infants? The fact that fullterm infants only succeeded after a longer period of familiarization might indicate that infants need additional familiarization time along with additional attentional time to accomplish the task. Therefore, testing this ability in preterms will allow us to explore whether segmentation is achieved despite increasing the complexity of the stimuli (by embedding the syllabic unit and extending the total experimental time), and consequently, the cognitive demands. It has been suggested that failure to achieve a task in preterm infants may be due to the degree of task complexity and the amount of cognitive load that it requires (Bosch, 2011). Furthermore, a recent meta-analysis on

very preterm children has also concluded that as language functions become more complex, they experience more difficulties (van Noort-van der Spek, et al., 2011). If increasing task complexity by presenting preterm infants at 6 months of postnatal age with embedded syllables and lengthening the familiarization as well as the duration of the experiment increases the cognitive load, we expect preterm infants to exhibit no segmentation effect. However, if the syllabic unit is a basic cue that can be easily segmented (as suggested by our finding that 4-month-old fullterms segment monosyllabic words, Experiment 2), preterm infants at 6-months postnatal age might show successful segmentation.

METHOD

Participants

The participants were twenty-four preterm infants (11 females and 13 males), with a mean postnatal age of 6 months and 13 days (range: 6 months and 1 day to 7 months and 1 day). Half of the infants were very preterm infants (except for 2 infants born at 32 GW and 1 day and 32 GWs and 2 days included preliminarily in the “very preterm subgroup” to have the same number of participants in each subgroup) and the other half were born moderate to late preterms. All infants were recruited via i) a hospital (Hôpital Robert Debré, Paris), ii) a parents’ association of preterm infants in France or iii) birth lists issued by the Paris city registry office. The sample included families with a large range of socioeconomic status. All parents gave informed consent before participation. The inclusion criteria were being monolingual (more than 80% of input in French), with no reported hearing or serious health problem (brain injury, long retinopathy or surgical intervention). Infants’ language background and health was assessed using an information sheet, an interview and the medical information provided in the child health record (“carnet de santé”). Twenty-one additional infants did not complete the experiment due to difficulties turning their head (5), fussiness or distraction (2), crying (7), parental interference (2), or technical problems (4) and segmentation index more than 2 *SD* above or below the group mean (2).

In order to determine whether the included infants were more mature or healthier than the excluded ones (not taking into account the infants excluded due to technical problems), one-tailed t-tests were performed between the two groups (see Table 1.1). Included infants tended to have a higher gestational age, birth weight, 1-

and 5-minute Apgar, and shorter stay in the hospital, but these differences failed to reach significance.

Table 1.1. Clinical neonatal characteristics of the sample included (n=24) and excluded (n=17).

| | Included (N=24) | Excluded (N=17) | Difference (1-tailed t-tests) |
|---|-----------------------------|-----------------------------|----------------------------------|
| Neonatal History (values correspond to mean, SD and range) | | | |
| Gestational age (wk) | 31.7 (2.5) range: 25-34 | 30.3 (3.2) range: 25-35 | $t(39) = -.75, p = .23$ |
| EPT (<28 wks, <i>n</i>) | 1 | 2 | |
| VPT (28<32) | 9 | 6 | |
| MPT (32<34) | 10 | 6 | |
| LPT (34<37) | 4 | 3 | |
| Birth weight (g) | 1.514(509) range: 620-2.460 | 1.432 (461) range: 580-2180 | $t(39) = -.52, p = .30$ |
| Stay in hospital (days) | 48.5 (25.3) range: 15-103 | 59.8 (38.6) range: 20-155 | $t(39) = 1.53, p = .13$ |

Stimuli

The stimuli used were identical to those employed in Experiment 3 of Nishibayashi et al., (2015). The four syllables used in the present experiment are the same as those in Experiment 1 and 2, which have relatively low frequencies, as reported in the adult database LEXIQUE 2. The frequency for the syllables in the initial and final positions of French bisyllabic words are the following: /di/ (initial position: 20.47; final position: 3.06); /po/ (initial position: 1.55; final position: 13.65); /te/ (initial position: 7.79; final position: 8.56) and /gu/ (initial position: 3.08; final position: 6.72). For each syllable, eight bisyllabic target words that start (four) or end (four) with that syllable were also chosen for their relatively low frequencies. As in Experiment 1, an eight-sentence passage was created for the familiarization phase for each target syllable. Again, the target words appeared towards the beginning (four times) or the end (four times) of the sentences, and syllables preceding and following the target words were always different. (See Appendix 2).

The female talker of Experiment 1 recorded the passages and the four lists of 20 target syllables following the same recording instructions. Mean values of syllable duration, intensity and pitch for passages and lists are reported in Table 1.2.

Table 1.2. Acoustic measurements of target syllables (from Nishibayashi et al., 2015).

| | Initial syllable | Final syllable | Words in lists |
|----------------|---------------------|-------------------|-------------------|
| Duration (ms) | 145 | 161 | 321 |
| Intensity (dB) | 74.4 | 74.8 | 74.7 |
| Pitch (Hz) | 214 | 232 | 216 |

Procedure, apparatus and design

The procedure, apparatus and design were identical to Experiment 1 and 2 except for the familiarization time that is now of 45 seconds for each passage (instead of 30 seconds).

RESULTS

Mean orientation times (OTs) were calculated for the lists containing the target embedded syllables versus the control syllables (Figure 1.1). A repeated-measures ANOVA with mean OTs as the dependent measure, subgroup (extremely/very preterm vs. moderate/late preterm) as between-group factor and familiarity (target vs. control) as within-group factor was conducted. The effect of familiarity was significant ($F_{(1,22)} = 6.30$; $p = .02$, $\eta^2_p = .221$). Infants listened longer to control syllables ($M = 10.05$; $SD = 3.45$) than to familiar syllables ($M = 9.20$; $SD = 3.16$). This pattern of preference for target syllables was found in 20 of the 24 infants. Neither the effect of subgroup ($F_{(1,22)} = 1.57$; $p = .22$; $\eta^2_p = .067$) nor the subgroup x familiarity interaction ($F_{(1,22)} = .27$; $p = .60$; $\eta^2_p = .012$) were significant, failing to reveal an effect of degree of prematurity.

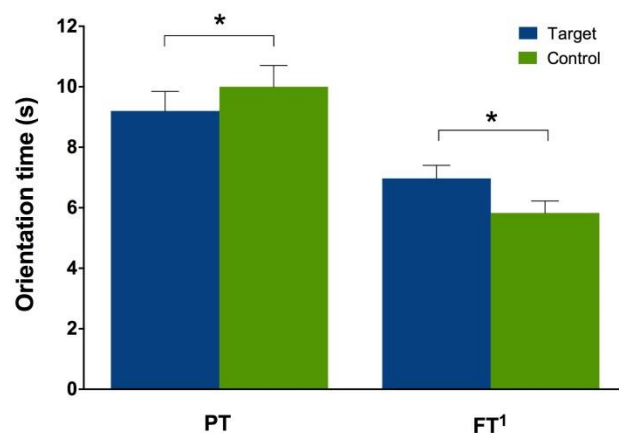


Figure 1.1. Orientation times to target and control syllables for the preterm group (left), and fullterm group (right). ¹Data from Nishibayashi et al., 2015.

To further evaluate the possible modulation of the segmentation effect, correlations were run between the novelty effect (attesting segmentation) and infants' gestational ages, birth weights and duration of hospital stay. All Pearson correlations (unilateral) between difference scores (orientation times to target minus control syllables) and infants' characteristics failed to reach significance (gestational age: $r = -0.060$; $p = .39$; birth weight: $r = 0.068$; $p = .38$; stay in hospital: $r = -0.16$; $p = .22$).

DISCUSSION

The present experiment aimed at providing evidence regarding whether preterm infants at the same postnatal age as their fullterm peers are able to segment an embedded syllables in bisyllabic words from fluent speech. Our results demonstrate that preterm infants succeed at segmenting embedded syllables at 6 months postnatal age. However, the behavioral pattern observed differs from the one found in the fullterm population tested under the same conditions (same language and laboratory: Nishibayashi et al., 2015). In other words, preterm infants showed a novelty effect whereas fullterm infants had a familiarity effect. Given these group difference, the present findings suggest that while both groups of French-learning infants show successful segmentation of embedded syllables, the underlying (cognitive resources) processes/different mechanisms that they rely on to achieve this task may differ.

The present results add to the previous results of Experiment 1 showing successful segmentation of monosyllabic CV words by demonstrating that preterms can also segment syllabic units when they do not correspond to word units. Furthermore, they show that preterm infants can cope with an increase in task difficulty. Experiment 3 presented infants with at least two sources of additional difficulty. First, the speech signal likely provides less prosodic cues when a syllable is embedded in a bisyllabic word compared to when the syllabic unit corresponds to the word unit. Second, the familiarization time was lengthened, and as a result, the duration of Experiment 3 was longer than that of Experiment 1, requiring attention and behavioral responses for a longer period.

With respect to the novelty effect observed, many studies investigating segmentation abilities have mainly argued that, at the same age, it has been proposed that infants show familiarity effects in easier tasks and novelty effects in more difficult ones. In addition, it has been associated to a developmental change. When everything

else is held constant, younger infants would show a familiarity preference and older infants would switch to a novelty preference, as they improve their linguistic abilities, gain in (cognitive) maturation and are better able to encode new information. The idea behind this behavioral response has been put forward, among others, by Hunter and Ames (1988). This familiarity-novelty switch as a function of age has been reported in some segmentation and categorization studies (Bosch et al., 2013, Perszyk et al., 2016). However, segmentation studies have yielded familiarity (refs) and novelty responses (Polka & Sundara, 2012) in typically developing infants around the same age. Moreover, a recent meta-analysis tested the model proposed by Hunter and Ames (1988) by including the results from 168 experiments carried out in the last twenty years on word segmentation of natural speech (Bergmann & Cristia, 2016). No switch from familiarity to novelty was observed as a function of age, suggesting that Hunter and Ames (1988) model may not be the most appropriate to interpret the direction of word segmentation effects. Accordingly, the novelty effect observed in the present experiment may not be considered as an indicator of better linguistic ability in preterm infants' segmentation of embedded syllables, since their linguistic development may not follow a typical trajectory. Alternatively, our findings may point to the fact that preterm infants may use partly different speech processing mechanisms than fullterm infants.

In fact, other studies comparing preterm and fullterm infants have provided evidence for a given linguistic ability in both groups while observing contrasting responses. For instance, in an ERP study investigating speech sound discrimination at term equivalent age, both fullterm and preterm infants discriminated frequent and infrequent speech sounds. However, both groups showed an opposite pattern of response in polarity and it was found on different scalp sites (Therien et al., 2004). The authors suggest that these differences might be related to the use of different neural structures. Other work has reported different activation patterns between children born very preterm and fullterm children in response to semantic stimuli (Peterson et al., 2002) and correlations between white matter abnormalities and linguistic performance in standardized tests (Reidy et al., 2013; Feldman, et al., 2012). In addition, other recent research mainly on very preterm infants has provided evidence of alterations in the brain architecture, including grey and white matter, corpus callosal areas or thalamic development (Ball et al., 2013; Inder et al., 2005; Inder et al., 2003; Iwata et al., 2012; Thompson et al., 2011) which could lead to different information/speech processing mechanisms. Despite the failure to find a link

between the segmentation effect (difference score) and gestational age in the present study, it remains possible that correlations between measures of brain regions and neurodevelopmental outcomes emerge in larger groups of infants. Thus, although our current understanding of the role of prematurity in language development remains largely unknown, it is possible that premature infants use different procedures and neural processes than fullterm children. The pattern of results of the present experiment may represent behavioral evidence of such differences.

Regarding the lack of degree of prematurity within the preterm group, it is worth noting that the present results parallel those of Experiment 1 on monosyllabic word segmentation. As argued in the discussion of Experiment 1, we must interpret this outcome with caution for two main reasons: the limited number of participants in each subgroup and the high rejection rate observed. Regarding the latter point, comparisons between included and excluded infants did not yield significant differences. However, we acknowledge the need to gather more detailed clinical information for the preterm infants tested in the present experiment to better specify high- and low-risk infants and their subsequent language development.

In future research, it will be important to examine when and how preterm infants segment more complex linguistic stimuli, such as bisyllabic words, and what is the contribution of postnatal and maturational age to this accomplishment. Moreover, future studies should examine the possible links between early segmentation abilities and later lexical outcomes, as reported in fullterm infants (Junge & Cutler, 2014; Junge et al., 2012; Kooijman et al., 2013; Newman, Ratner, Jusczyk, Jusczyk, & Dow, 2006). Using other measures of brain activity (EEG, fMRI, NIRS) should be encouraged to gain better insights of the underlying speech processing mechanisms involved in lexical development in preterm born infants.

To sum up, extremely-to-late preterm infants acquiring French segment the rhythmic unit of their native language, the syllable, at the same postnatal age as their fullterm counterparts. Specifically, Experiment 3 has found that preterm infants are able to segment syllabic units embedded in bisyllabic words at 6 months of postnatal age similarly to their fullterm peers (note: neither fullterm nor preterm infants were tested at younger ages on this task) despite an increase of cognitive demands with respect to monosyllabic word segmentation (Experiment 1). The direction of effect differed between the two groups, which might reflect differential underlying speech processing,

an issue that deserves to be further explored longitudinally using various techniques and types of words.

4. Experiment 4. Emergence of a consonant bias? Preterm infants at 8 months

The majority of languages have more consonants than vowels (Maddieson & Diesner, 1984). In fact, the average ratio of consonants/vowels worldwide is around three, meaning that for every three consonants, there is one vowel (The World Atlas of Language Structures). From a theoretical point of view, it has been proposed that consonants and vowels play a different role in language processing and language acquisition, namely, that consonants would have a more important weight for lexical recognition and vowels would carry more information related to the prosodic properties of the language (Nespor, Peña, & Mehler, 2003). Indeed, evidence from visual word recognition experiments in adults has demonstrated that consonant and vowels have a differential role in word processing. For example, in the auditory domain, research in word identification has found that it is easier for adults to track statistical information from consonants than from vowels, which also points at consonants as better candidates for lexical recognition (Bonatti, Peña, Nespor, & Mehler, 2005). Priming experiments have also established more priming for consonant than for vowel information in both the visual and the auditory domains (Perea & Lupker, 2004; New, Araujo, & Nazzi, 2008; Delle Luche et al., 2014). Moreover, in the audiovisual domain, the matching between sounds and round or spiky shapes (known as the bouba-kiki effect) is more influenced by consonant than vowel identity (Fort, Martin, & Peperkamp, 2014).

To determine the origin of this differential role, one needs to examine infants' preferential processing of vowels and consonants in development. In a lexical acquisition task, Nazzi (2005) showed that 20-month-old French-learning children could learn two different label-object associations when the labels differed by one consonant (e.g. /pize/ - /tize/) but not when they differed by one vowel (e.g. /pize/ - /pyze/). To further investigate whether the consonant bias (C-bias) in lexical processing is innate or acquired, and whether it is language dependent, a number of crosslinguistic studies have been published on the first two years of life in typically developing infants. Regarding the earliest stages of language acquisition, a study conducted on Italian newborns has found that they remember better vowel than consonant information from previously presented words (Benavides-Varela, Hochmann, Macagno, Nespor, & Mehler, 2012), indicating that vowels might be preferentially processed at birth. This initial processing advantage of vowels differs from evidence obtained by the end of the first year. Two studies in Italian- and French-learning infants have reported

a C-bias in word recognition using different tasks (Hochmann, Benavides-Varela, Nespor, & Mehler, 2011; Nazzi & Poltrock, 2015). The first study familiarized 12-month-old Italian-learning infants with two words presented auditorily (e.g., kuku, dede) that were followed by the appearance of an object either one side of the screen (e.g., right for kuku) or another (e.g., left for dede). During the test phase, infants were presented with words similar to the original ones, but the consonant and vowel combinations had been switched (e.g., keke, dudu). Upon hearing the word, anticipatory looks were measured to assess in what location infants predicted the toy to appear. The results showed that they looked more to the original object location (e.g., kuku's location) if the vowel changed (e.g., keke) than if the consonant changed (e.g., dudu) (Hochmann et al., 2011). The second study tested 11-month-old French-learning infants' listening preference for consonant or vowel mispronunciations of familiar words. Infants preferred listening to vowel mispronunciations over consonant mispronunciations (Nazzi & Poltrock, 2015). Taken together, both studies suggest that, around the age of one year, consonant alterations have a greater impact on word recognition than vowel alterations, showing that the C-bias is already present at this age in French- and Italian-learning infants. So when in this first year of life do infants switch from a V-bias to a C-bias?

A vowel bias has been found during the first half of the year in French-learning infants at 5 months, at the onset of lexical acquisition. Bouchon and colleagues (2014) compared 5-month-olds' listening time preferences to consonant or vowel mispronunciations of their own name over an unfamiliar name. The results showed that these infants were more sensitive to a vowel mispronunciation than to a consonant mispronunciation. The authors proposed that the emergence of the C-bias would then take place between 5 and 11 months (Poltrock & Nazzi, 2015). To explore this prediction, Nishibayashi and Nazzi (2016) tested two groups of 6- and 8-month-old French-learning infants. They used a segmentation task to analyze this phenomenon because evidence for segmentation skills, as reflected by familiarity effects, had been previously found at both 6 and 8 months of age (Nishibayashi et al., 2015). In Experiment 3, infants were first familiarized with two target words in passages and, in the test phase, they were presented with a vowel and a consonant mispronunciation of the target words. At 6 months, infants listened longer to consonant mispronunciations than vowel mispronunciations. In other words, for 6-month-olds, consonant mispronunciations are more similar to the familiar words, reflecting a V-bias (see Figure

1.2., right panel, from Nishibayashi & Nazzi, 2016). On the other hand, 8-month-olds listened longer to vowel mispronunciations than to consonant mispronunciations, meaning that they consider vowel mispronunciations as more similar to the familiar words, reflecting a C-bias (Figure 1.2, left panel). According to these results, the C-bias emerges between 6 and 8 months in French-learning infants.



Figure 1.2. Mean orientation times (and SEs) to C-MP vs. V-MPs for 8-month-olds (left panel) and 6-month-olds (right panel). *** = $p < .001$. Figure from Nishibayashi and Nazzi (2016).

Preterm infants are an interesting case to explore the emergence of the C-bias because their premature birth gives them earlier access to high frequency sounds otherwise not heard in the womb (mostly corresponding to consonants). For instance, a recent study on vowel and consonant auditory processing in preterm infants has shown that (ERP) responses to consonant contrasts (e.g. /b/-/d/) were more affected than responses to vowel contrasts (e.g. /a/-/u/) by both the effect of gestational age and postnatal age (Key et al., 2012). The authors propose that this differential effect could stem from the fact that vowels are more stable sounds that differ importantly in frequency and may be more easily distinguished. Importantly, their results also demonstrate that children born later in gestation or those that are chronologically older show a greater difference in the ERP amplitude to the consonant contrasts. These findings are consistent with the ‘acoustic/phonological hypothesis’ (Floccia et al., 2014) which states that the acoustic differences between consonants, usually shorter and less steady than vowels, set the foundation for a distinct role of each category in development. As explained by Floccia and colleagues (2014), the emerging role of each category would be the result of the interplay between early perceptual biases and

language-specific properties. Evidence to date from crosslinguistic studies has shown that the c-bias emerges around the age of 30 months in English-learning infants (Floccia, Nazzi, DelleLuche, Poltrock, & Goslin, 2014) or that a V-bias is present at 20 months in Danish-learning infants, a language that has more vowels than consonants (Højen & Nazzi, 2016; for a review of crosslinguistic differences see Nazzi, Poltrock & Von Holzen, 2016).

In the present experiment, we explore the claim that postnatal age determines the timing of emergence of the C-bias by testing preterm infants. This is because high frequency sounds (most of them corresponding to consonants), are only heard after birth. As mentioned before, previous studies in our laboratory have demonstrated that the C-bias emerges between 6 and 8 months in fullterm French-learning infants (Nishibayashi & Nazzi, 2016). Here, we investigate if preterm infants at 8 months postnatal age behave like fullterm infants matched on postnatal age (8-month-olds) or like fullterms matched on maturational age (6-month-olds). We selected Experiment 3 of Nishibayashi & Nazzi (2016) that uses a segmentation task to assess the impact of a consonant or vowel mispronunciation on the segmented word. If preterm infants showed a C-bias, it would provide evidence of the contribution of postnatal age to acquire such processing bias. On the other hand, if they showed a V-bias, it could be due to maturational constraints or to reduced exposure to low frequency sounds in utero. However, it is also possible that infants would show no preference for either the vowel or consonant mispronunciation. Indeed, the present segmentation task requires extracting a monosyllabic familiar word from the speech stream and “matching” it to a similar word (involving a vowel or consonant mispronunciation) instead of matching to the familiar word heard during the familiarization. This task could require more complex cognitive abilities than the standard segmentation tasks used in Experiments 1 and 3, and thus revealing limits in segmentation skills.

METHODS

Participants

The participants were seventeen preterm infants (10 females and 7 males), with a mean postnatal age of 8 months and 16 days (range: 8 months and 5 days to 8 months and 27 days). The group will be completed to 24 infants. From the seventeen infants, 7 were extremely/very preterm infants (mean GWs = 30.06, *SD* = 0.6) and 10 were born moderate/late preterm (mean GWs = 34.93, *SD* = 1.4). All infants were

recruited via i) a hospital (Hôpital Robert Debré, Paris), ii) a parents' association of preterm infants in France or iii) birth lists issued by the Paris city registry office. The sample included families with a large range of socioeconomic status. All parents gave informed consent before participation. The inclusion criteria were being monolingual (more than 80% of input in French), with no reported hearing or serious health problem (brain injury, long retinopathy or surgical intervention). Infants' language background and health was assessed using an information sheet, an interview and the medical information provided in the child health record ("carnet de santé"). Five additional infants did not complete the experiment due to fussiness or distraction (4), and segmentation index more than 2 *SD* above or below the group mean (1).

Stimuli

Stimuli were the same as of Experiment 3 of Nishibayashi & Nazzi (2016) but we only used the CVC condition for being the condition that had larger effects in that experiment. Sixteen CVC words were selected (see Appendix 3). All the words were common nouns (except /ruz/ - Rouze which is a French town) with relatively low frequencies, as given in the adult database LEXIQUE 3.5 (New, Pallier, Brysbaert, & Ferrand, 2004, values given per 1 million occurrences, and calculated over a base of 31 million occurrences). The words were also chosen so that each word could be used as a target word in the familiarization phase or as a V-MP or C-MP in the test phase. As a result, across infants 4 consonantal contrasts were used (4 for consonants and 4 for vowels) and within the vowel contrasts 2 height and 2 place were used (see Table 1.3., from Nishibayashi & Nazzi, 2016).

Table 1.3. Frequency of the CVC words (from Nishibayashi & Nazzi, 2016).

| Stimuli | Frequency | French spelling | English translation |
|---------|-----------|-----------------|---------------------|
| /kɔl/ | 51.82 | col | collar |
| /sik/ | 0.20 | sikh | sikh |
| /kur/ | 176.76 | cours | course |
| /sɛ̃t/ | 0.34 | set | placemat |
| /kɔr/ | 2.36 | cor | horn |
| /sit/ | 3.58 | site | site |
| /kul/ | 0.88 | coule | monk mantle |
| /sɛ̃k/ | 0.88 | sec | dry |
| /rys/ | 15.54 | russe | Russian |
| /bag/ | 16.08 | bague | ring |
| /ruz/ | 0 | Rouze | Rouze |
| /bɛ̃k/ | 23.31 | bec | beak |
| /ryz/ | 13.31 | ruse | ruse |
| /bak/ | 13.99 | bac | bin |
| /rus/ | 5.61 | rousse | redhead |
| /beg/ | 0.41 | bègue | stutterer |

Procedure, apparatus and design

The procedure, apparatus and design were identical to Experiment 1.

RESULTS (preliminary)

Mean orientation times (OTs) were calculated for the lists containing the C-MPs versus the lists containing the V-MPs. A repeated-measures ANOVA with mean OTs as the dependent measure, subgroup (extremely/very preterm vs. moderate/late preterm) as a between-group factor and familiarity (V-mispronunciation vs. C-mispronunciation) as a within-group factor was conducted. The effect of familiarity was not significant ($F_{(1,15)} = 1.81$; $p = .20$, $\eta_p^2 = .107$). Neither subgroup ($F_{(1,15)} = .23$; $p = .88$, $\eta_p^2 = .002$) nor the subgroup x familiarity interaction were significant ($F_{(1,15)} = 1.70$; $p = .21$, $\eta_p^2 = .102$), failing to reveal an effect of the degree of prematurity on the expression of the C-bias.

To start evaluating the possible modulation of the bias with maturation, Pearson correlations (unilateral) were run between difference scores (OTs to V-mispronunciation – OTs to C-mispronunciations) and infants' gestational ages and birth weights. Correlation between difference score and gestational age was significant ($r = -0.51$; $p = .02$), indicating that preference for V-mispronunciation (reflecting a consonant bias) was

associated to younger gestational ages. Correlations between difference scores and birth weights did not reach significance ($r = -0.36$; $p = .08$).

DISCUSSION

Based on previous evidence on fullterm infants showing a switch from a vowel bias (V-bias) at 6 months to a consonant bias (C-bias) at 8 months (Nishibayashi & Nazzi, 2016), this experiment considered the hypothesis that preterm infants would show a consonant bias if postnatal exposure to high frequency sounds after premature birth crucially contributes to the emergence of this bias. The second possibility was that preterm infants would exhibit a vowel bias if maturational age and/or lack of intrauterine exposure to low frequency speech sounds contribute to a large extent to the emergence of the C-bias in preterm infants. No significant difference was found, failing to show that preterm infants at 8 months of postnatal age have either a consonant or a vowel bias.

Different reasons could explain failure to find a vowel or a consonant bias. As previously suggested, the task might have been too complex for preterm infants, since it uses segmentation abilities to test the consonant or vowel bias by means of presenting mispronunciations of the familiar word in the test phase. Although evidence for segmentation of monosyllabic words was found in Experiment 1, segmentation abilities might not be as well established in preterm infants as in the fullterm population, rendering the comparison of the mispronounced words to the familiar word too complex at this age. A second reason would be related to the number of infants included in the present experiment. Possibly, the limited number of participants did not allow to observe either a vowel or a consonant bias and we will increase the number of participants included by testing further infants. Moreover, to explore the emergence of the C-bias, other types of tasks with different complexity could be used. For example, using an audiovisual method as in (Hochmann et al., 2011) might render the task easier for the preterm population if visual cues help speech processing. At this point, our preliminary data does not allow us to answer the experimental question of the contribution of postnatal and maturational age to the emergence of the C-bias.

Our preliminary analyses also revealed a significant correlation between gestational age and type of bias. Infants born earlier in gestation tended to listen longer to vowel mispronunciations (corresponding to a C-bias). These results are counterintuitive. Given that all preterm infants had the same exposition to broadcast

speech, infants born later in gestation would have had more intrauterine exposition to low frequency sounds, thus having a more similar experience to infants born at term, therefore, we would have expected that the preference for vowel mispronunciations (hence, the C-bias) would be associated to moderate and preterm birth. At this point it is difficult to interpret this correlation given that the subgroups were small and not balanced (7 out of 17 were extremely/very preterm). If this correlation is confirmed in the future adding infants to the groups, the question of the emergence of the C-bias in vulnerable populations will have to be assessed more thoroughly. One possible way to do is to investigate whether this preference is found from birth onwards (Benavides-Varela et al., 2012), or whether it is related to the effect of high frequency sounds on an immature organism.

In summary, the present results fail to show the presence of a vowel or a consonant bias in preterm infants at 8 months postnatal age. We suggest that failure to find a bias may be due to the segmentation task used, and may reveal limitations in the abilities of preterm infants to segment speech. Future studies should pursue research in this domain since vowels and consonants represent the very basic units of the phonological system.

To close the present chapter, we will explore the effect of prematurity on basic segmentation abilities in another population: infants born/growing up in a bilingual environment.

5. Experiment 5. Monosyllabic word segmentation in bilingual preterm and fullterm infants at 6 months

Bilingualism is a term that refers to the ability to speak two languages to different degrees of competence. In our globalized world, an increasing number of people move from their native country to a new one where they might settle down and start a new life. In cities like Paris, 15% of its population was born in another country, and in other cities like London or Berlin, it represents 26% and 11% respectively (Atelier Parisien d'Urbanisme, 2014). These newcomers might meet a partner, and might eventually have children, who will grow up listening to their parents' native languages from birth (and even prenatally; Querleu et al., 1988; Nazzi et al., 1998). In this and many other bilingual contexts, infants will have to acquire two linguistic systems from birth, a complex task in nature because they have to process two different linguistic inputs. The linguistic environment of bilingual infants is characterized by less exposure to each language than monolinguals while paradoxically they have to separate information by its language, acquire a more complex perceptual space of phonetic categories and cope with more variability in the input (Byers-Heinlein & Fennell, 2013). In the last decade, researchers have started to pay more attention to bilingual infants in order to understand when and how they develop speech perceptual abilities. The goal of the next experiment was to explore how prematurity and bilingualism may impact word segmentation abilities.

To date, studies on auditory perception in these young bilingual populations have revealed that infants are sensitive to the exposure to two languages before birth. One line of research explored language discrimination. Newborns whose mothers speak two rhythmically different languages during pregnancy —stress-timed (English) and syllable-timed (Tagalog)— are similarly interested in both languages whereas newborns from English monolingual mothers prefer to listen to English (Byers-Heinlein et al., 2010). Moreover, they are able to discriminate between both languages, similarly to monolingual newborns' discrimination of rhythmically-different languages (Byers-Heinlein, et al., 2010; Nazzi et al., 1998). By 4 months, bilingual infants can also discriminate their native languages when both are rhythmically similar (Spanish-Catalan: Bosch & Sebastián-Gallés, 2001) and also one of their native languages from a rhythmically similar nonnative language (e.g., Italian; Bosch & Sebastián-Gallés, 1997). A second line of research comes from the studies of the discrimination of lexical patterns. It reveals

that bilingual infants are sensitive to the most frequent lexical pattern of one of their native languages. For instance, 6-month-old French-German bilingual infants show a trochaic bias, as reported for monolingual German-learning infants and in contrast to monolingual French-learning infants who do not show any preference for either trochaic nor iambic patterns (Bijeljac-Babic, Höhle, & Nazzi, 2016; Höhle, et al., 2009). Taken together, these studies suggest that bilingual infants use language-specific prosodic and phonological information to separate both linguistic systems.

Evidence from segmentation studies in monolingual infants has led to the idea that while some segmentation strategies like the use of statistical cues are general mechanisms used by monolingual infants regardless of their language background (refs), other procedures are based on language-specific cues. For example, French-learning infants do not segment trochaic words in English and English-learning infants do not segment iambic words in French, while the reverse is true (Polka & Sundara, 2012). Recent data has demonstrated that 6- and 8-month-old bilingual infants of two similar rhythmic languages (Spanish and Catalan) segment monosyllabic words in their dominant language at the same age as their monolingual peers (Bosch et al., 2013). In another study, 8-month-old French-English bilingual infants were tested on their segmentation skills in both languages using a dual-language task (Polka, Orena, Sundara, & Worrall, 2017). Infants were first familiarized with one passage in one language and tested with the familiar versus a control word. Then they were tested with the same procedure in the other language. The results showed that bilingual infants segmented French bisyllabic words, but only when French was presented in the first experimental session. No segmentation effect was found for English. In a following experiment, French-English bilingual infants were tested only in English using the standard procedure. Bilingual infants segmented the bisyllabic English words. Despite the methodological issues related to the dual-task, the authors suggests that the differences between Bosch et al.' (2013) results and their findings could be explained by the type of words used (monosyllabic versus bisyllabic), the language(s) tested (dominant only versus both languages) and the fact that the segmentation skills that bilinguals have to develop depend on the rhythmic unit of both of their languages when they are exposed to rhythmically different languages, but only need to learn one procedure if the languages have similar rhythms.

What the prior work has in common is that one of the languages that the bilingual infants were acquiring was a syllable-timed language (Catalan, Spanish or

French) and both showed successful segmentation of target words in that language. However, as pointed out by Polka et al. (2017), both studies differ in the type of words segmented and the type of languages bilinguals were exposed to. Given that French-English bilingual infants segment iambic-like words in French at 8 months, they presumably segment monosyllabic words before this age. However, no research to our knowledge has explored this issue in bilinguals exposed to different combinations of rhythmic languages, at least one of them being a syllabic-time language.

The present experiment aimed to explore monosyllabic word segmentation in a diverse bilingual population. The ideal context for such an experiment would have been to target a homogenous bilingual group having two rhythmically different languages (e.g., French-English) and a homogenous bilingual group having two rhythmically similar languages (e.g., French-Italian) and test them on their ability to segment words from fluent speech in French. Unfortunately, such groups are experimentally difficult to constitute. Therefore, we decided to start exploring this issue by testing infants who are acquiring a syllable-timed language (French) and another language (syllable-, stress-, mora-timed) but who are equally exposed to both languages on a daily basis or who have French as their dominant language. We will explore how two life experiences, being preterm and being bilingual, might affect word segmentation abilities. In other words, we will keep the focus of the present research on prematurity, by testing a group of bilingual preterm infants at 6 months of postnatal age and compare them with a group of 6-month-old bilingual fullterm infants. We use the same monosyllabic word segmentation task as in Experiments 1 and 2 (set-up for fullterm 6-month-olds by Nishibayashi et al., 2015). Regarding prematurity, few studies to our knowledge have studied the possible influence of bilingualism and of the complexity that processing two linguistic inputs entails for the immature brain. For instance, a recent line of research has started to investigate whether cognitive advantages in executive control associated to bilingualism (Bialystok & Viswanathan, 2009) could benefit the preterm population (Loe & Feldman, 2016; Walch, Chaudhary, Herold, & Obladen, 2009; for a review, Head, Baralt, & Mahoney, 2015). Exploring segmentation abilities in bilingual preterm infants will provide us further knowledge about the possible interaction of these two factors on the emergence of word segmentation abilities.

If bilingual infants in the present experiment follow the same pattern of emergence of segmentation abilities as previous work on bilinguals who are acquiring at least one syllable-timed language, we expect balanced and French-dominant

bilinguals to succeed in segmenting monosyllabic words. However, if they fail, it would contribute new data to the debate on the use of the syllable as the default rhythmic unit for segmentation and the emergence of segmentation abilities in bilingual populations with diverse linguistic backgrounds. In the following, we will provide preliminary data, results and discussion on this research question.

METHOD

Participants

The preterm participants were seventeen infants (8 females and 9 males), with a mean postnatal age of 6 months and 14 days (range: 6 months to 6 months and 23 days). From the seventeen infants, 12 were extremely/very preterm infants (mean GWs = 28.24, $SD = 1.7$) and 5 were born moderate/late preterm (mean GWs = 33.74, $SD = 1.02$; see Table 1.4. for details on degrees of prematurity). The fullterm participants were ten infants (4 girls and 6 males), with a mean age of 6 months and 11 days (range: 5 months and 29 days to 6 months and 29 days).

All infants were recruited via i) a hospital (Hôpital Robert Debré, Paris) or ii) regular laboratory recruiting through the birth lists issued by the Paris city registry office. All parents gave informed consent before participation. Infants were included if they were exposed to French and another language and if (parental) estimated rate of exposure to French was between 50-70 percent on a daily basis (for participants' other-language exposure, see Table 1.4). Only infants with no reported hearing or serious health problem (brain injury, long retinopathy or surgical intervention) were included. Infants' language background and health was assessed using an information sheet, an interview and the medical information provided in the child health record ("carnet de santé"). Ten additional preterm infants did not complete the experiment due to failure to consistently turn their heads (3), fussiness or distraction (1), crying (3), or technical problems (1), parental interference (1), and segmentation index more than 2 SD above or below the group mean (1). To examine whether excluded preterm infants differed from included preterm infants in gestational age and birth weight, t -tests were performed, excluding the infant rejected due to experimental error (see Table 1.5.). No significant differences were found between both groups.

Table 1.4. Language background of preterm and fullterm participants.

| Language | Preterm (N=17) | | Fullterm (N=13) | |
|------------------|-------------------|------------------------|--------------------|------------------------|
| | Balanced (n) | French-dominant (n) | Balanced (n) | French-dominant (n) |
| Arabic | 4 | 5 | | 1 |
| Italian | 1 | 1 | | 1 |
| Spanish | 1 | | | 1 |
| Bambara | 1 | | | |
| Malgache | 1 | | | |
| Creole (Guyane) | | 2 | | |
| Mandarin Chinese | 1 | | 1 | |
| Libanais | | | | 1 |
| Persan | | | | 1 |
| Kasshonke (Mali) | | | | 1 |
| Soninke | | | | 1 |
| Russian | | | | 1 |
| Japanese | | | | 1 |

Table 1.5. Neonatal characteristics of preterm infants.

| | Included (N=17) | Excluded (N=9) | Difference (1-tailed t-tests) |
|---|------------------------------|-----------------------------|----------------------------------|
| Neonatal History | | | |
| (values correspond to mean, SD and range) | | | |
| Gestational age (wk) | 29.9 (3.0) range: 26-35 | 32.17 (3.7) range: 25-35 | $t(24) = -1.72, p = .95$ |
| EPT (<28 wks, <i>n</i>) | 7 | 2 | |
| VPT (28<32) | 5 | 1 | |
| MPT (32<34) | 2 | 1 | |
| LPT (34<37) | 3 | 5 | |
| Birth weight (g) | 1.294 (396) range: 670-2.110 | 1.605(603) range: 780-2.300 | $t(24) = -1.59, p = .94$ |

Stimuli, procedure, apparatus and design were the same as in Experiment 1.

RESULTS

Mean orientation times (OTs) were calculated for the lists containing the target versus the control monosyllabic words. A repeated-measures ANOVA with mean OTs as the dependent measure, group (preterm vs. preterm) as a between-group factor and familiarity (target vs. control) as a within-group factor was conducted. The effect of familiarity was significant ($F_{(1,25)} = 10.86$; $p = .003$, $\eta_p^2 = .303$), infants having longer orientation times to target ($M = 9.31$ s, $SD = 3.11$) than to control ($M = 8.25$ s, $SD = 3.22$) words, indicating successful word segmentation. This pattern of preference for target words was found in XX of the 27 infants. Neither the effect of group ($F_{(1,25)} = .059$; $p = .81$, $\eta_p^2 = .002$) nor the group x familiarity interaction ($F_{(1,25)} = 1.081$; $p = .308$, $\eta_p^2 = .041$) were significant, failing to reveal an effect of prematurity. Although no interaction was found, we looked at the familiarity effect in the two groups. In the preterm group, the difference between target versus control failed to reach significance ($t(16) = 2.07$; $p = .05$; Cohen's $d = .503$) but was significant in the fullterm group ($t(9) = 2.34$; $p = .04$; Cohen's $d = .742$) (see Figure 1.4).

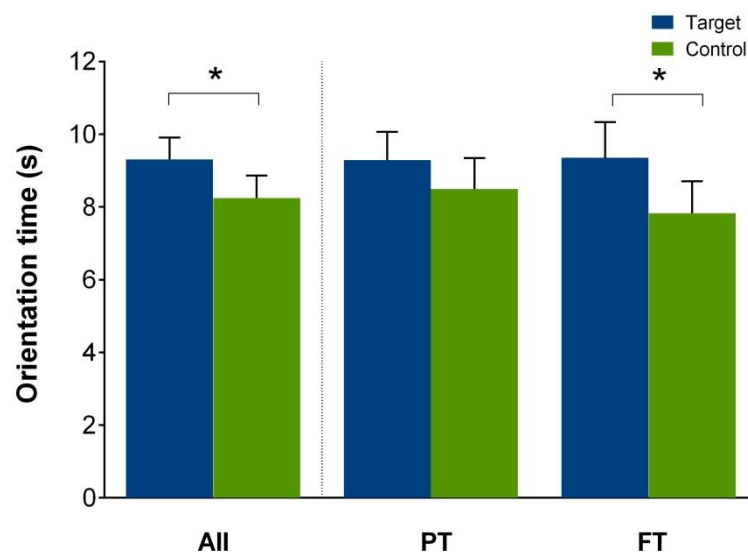


Figure 1.4. Mean orientation times for all bilingual infants (left), preterm infants (middle) and fullterm (right) for target and control words.

To explore the potential effect of degree of prematurity, we also conducted an ANOVA with mean looking time as the dependent measure, subgroup (extremely/very preterm vs. moderate/late preterm) as a between-group factor and familiarity (target vs

control) as a within-factor. Neither the effect of familiarity ($F_{(1,15)} = 3.46$; $p = .08$, $\eta_p^2 = .187$), subgroup ($F_{(1,15)} = .76$; $p = .40$, $\eta_p^2 = .048$), nor the interaction familiarity x subgroup ($F_{(1,15)} = .01$; $p = .94$, $\eta_p^2 = .000$) were significant. Furthermore, Pearson correlations (unilateral) between difference score (target – control) and gestational age ($r = -.076$, $p = .386$) and birth weight ($r = -.315$, $p = .109$) were not significant.

DISCUSSION

The goal of the present experiment was to explore whether early segmentation abilities are present in 6-month-old preterm and fullterm bilingual infants who have different linguistic environments, but were selected to be exposed to French between 50 and 70% of the time on a daily basis. They were tested on monosyllabic word segmentation in French using the passage-word order procedure (Nishibayashi et al., 2015; current Experiment 1). The preliminary results show that, taken together, preterm and fullterm infants segment monosyllabic words from fluent speech, indicating that balanced or French-dominant bilingual infants achieve this task despite receiving less exposure to French than their monolingual peers. At this preliminary stage (groups being less than half completed) only tendencies are found for each group separately.

Our results point in the same direction as previous evidence from bilinguals exposed to two syllable-time languages who succeed at segmenting monosyllabic words at the same age as their monolingual counterparts (Bosch et al., 2013). Interestingly, in contrast with Bosch et al. (2013) and Polka et al. (2017), including infants from diverse linguistic background in the present group did not prevent us from observing their abilities to segment monosyllabic words in French. This suggests several possible explanations. One could be that the amount of input in French they have received by the age of 6 months is enough to elicit segmentation skills. This could be further supported by the results of Experiment 2 of the present chapter, showing that 4-month-old monolingual infants, who have also had less experience with French than 6-month-old monolinguals, show successful segmentation of monosyllabic words. This is also consistent with previous evidence of French-German bilingual infants showing a trochaic bias at 6 months like monolingual German-learning 6-month-olds, although they received less input in German (Bijeljac-Babic et al., 2016). A second possibility is that the syllabic unit is a very basic unit as evidenced by studies in newborn showing process syllables better than other linguistic sound forms (Bertoncini et al., 1988) or

the mora (Bertoncini, Floccia, Nazzi, Mehler, 1995). It is possible that this initial sensitivity (bias) for the syllable facilitates subsequent syllable-based word segmentation processes. In this sense, word segmentation would be innately guided by infants' early processing of speech at the syllabic level. However, this early processing bias does not necessarily imply that infants are capable of using this unit for segmentation until they progressively have gained enough experience with the rhythmic unit of their syllable-timed native language.

At any rate, successful segmentation is likely related to the linguistic profile of the group. The infants included in the study were balanced or French-dominant bilinguals who may use the segmentation procedure corresponding to the rhythmic unit of French. Evidence from word segmentation in bilingual adults had demonstrated that the segmentation procedure used to extract words in each of their languages depends on the characteristics of the dominant language (Cutler, Mehler, Norris, & Segui, 1989). In Cutler et al.' study (1989), French-dominant bilinguals performed like French monolinguals for French words and like English monolinguals for English words. However, English-dominant bilinguals' performed like English monolinguals for both English and French words. In light of these asymmetrical results, the authors proposed that *“syllabic segmentation is a (‘marked’) language processing routine which speakers develop and apply if their (dominant) native language encourages it”*. These results are difficult to reconcile with the more recent data on French-English bilingual infants tested on French and English word segmentation using a dual task (Polka et al., 2017). These results showed that French- but also English-dominant bilingual 8-month-olds segmented French words. However, the authors were cautious about their results due to the reduced number of participants in each subgroup (12 and 9, respectively). Thus, the question of how syllabic segmentation procedures are acquired needs to be studied in future studies including larger groups of bilingual infants with different language dominance profiles.

With respect to prematurity, our preliminary results do not show an effect of preterm/fullterm group, indicating no differences between bilingual preterm and fullterm infants' segmentation abilities at this point. Furthermore, although the ultimate aim of the study is to include two balanced subgroups of preterm infants (extremely/very preterm and moderate/late preterm) as in Experiment 1, most infants included in the present report were born very prematurely (12 out of 17) which are usually the most vulnerable and at greater risk for later language delays. Hence, these groups will have

to be completed in the future to get a clearer picture of the potential effect of degree of prematurity. Interestingly, one avenue to explore in the future is whether bilingualism might confer advantages for the developing preterm brain. Bilingualism has been associated to advantages in executive functions (Bialystok & Feng, 2009) but also to increases in the density of gray matter and in the fractional anisotropy in white matter tracts connecting the frontal and temporal lobes (Mechelli et al., 2004; Mohades et al., 2012). Given that gray and white matter affect executive functioning (Tullberg et al., 2004), the structural changes associated with bilingualism may prove to be beneficial to preterm infants, whose cortical white and gray matter are often remarkably reduced (Anjari et al., 2009; Munakata et al., 2013). If bilingualism affects the brain function and structure of preterm children as it has been reported for individuals born at term, bilingual acquisition may have positive anatomical effects in the developing preterm brain. Further research exploring linguistic skills in preterm bilingual children can provide new insights into the potential benefits of bilingualism for language (or other cognitive) development.

Finally, it is essential to acknowledge the limitations of the present experiment. The sample size is small, especially for the fullterm group, so the present results should only be considered preliminary. Furthermore, due to the diversity of language backgrounds of the population where the study took place, it was difficult to recruit the same language combination in all groups (the two preterm subgroups and the fullterm group). A third limitation is the absence of measures of socioeconomic status. It is possible that there is a larger range of socioeconomic status in families with an immigration background. For instance, previous studies on language acquisition (e.g., word recognition) have found differences in processing speed measures in children coming from different socioeconomic backgrounds (Fernald et al., 2013). Further studies aiming at investigating these interactions as well as bilinguals' developmental trajectories may contribute to a better understanding of the influence of the type of languages acquired and input-related influences on segmentation skills.

Despite its limitations, this is the first study in which non-homogenous bilingual groups have been tested in basic segmentation abilities. Although it is less precise experimentally, it is more representative of the reality of many societies, since homogeneous groups of balanced bilinguals are rather rare nowadays, except in bilingual regions or cities such as Barcelona or Montreal. It is important to highlight this point because in many cases, when bilingual children who have been exposed to

the “mainstream” language and another language during infancy arrive at daycare and school, they are usually considered as “two monolinguals” in one person (Grosjean, 1982) and the daycare providers usually only perceive language interaction in the children as (negative) interference. Given that research in the domain of bilingual language acquisition from birth is still scarce, the present study aims at highlighting the importance of further investigating fundamental linguistic skills in bilingual infants in order to provide the best knowledge for future educational purposes.

6. Chapter Discussion

The present chapter explored segmentation abilities in preterm infants and compared them to previous and current experiments on fullterm infants matched on postnatal age. The results of these experiments allow us to observe similarities and differences between both groups that we will discuss next. The segmentation effect found for monosyllabic words (Experiment 1) at 6 months postnatal age show not only that the basic tools for segmenting speech are in place similarly to their fullterm peers (Nishibayashi et al., 2015), but also that this ability does not seem to be affected by degree of prematurity. Initially we did not discard the possibility that preterm infants would not achieve segmentation, as previously reported by Bosch (2011) in Spanish/Catalan preterm infants at 8 months of maturational age. Nonetheless, we explored this issue using the simplest stimuli corresponding to the rhythmic unit of the native language (CV) and a reduced experimental time (Nishibayashi et al., 2015). We found successful segmentation of monosyllabic words, as reflected by a familiarity effect. Further, we found that younger fullterm infants show monosyllabic word segmentation, establishing the age of 4 months as the earliest evidence for segmentation skills in French-learning fullterm infants.

We then hypothesized that if the syllabic unit is a basic unit that has been reported to have a special status in newborns (Bertoncini et al., 1988), preterm infants would extract syllables even in more complex contexts and when they do not correspond to word units (embedded syllables, Experiment 3). Alternatively, if the cognitive demands were too high for preterms, no segmentation effect would be found. We used fullterm evidence of segmentation of an embedded syllable (Nishibayashi et al., 2015) to test this ability in preterm infants. Segmentation effects were found at the same age of 6 months, but the pattern observed (novelty) was opposite to the one observed for fullterm infants (familiarity). We argued that the differential pattern reported at this behavioral level might reflect different underlying mechanisms of speech processing.

Next, given that basic segmentation abilities were in place at 6 months postnatal age in preterms, we decided to investigate the possible emergence of a consonant-bias at 8 months postnatal age using a segmentation task, as previously reported in fullterm peers (Nishibayashi & Nazzi, 2016). The study aimed at investigating whether postnatal experience with speech would enable a consonant bias to emerge or whether maturational age and/or lack of intrauterine exposure to speech

would constraint this emergence, infants then showing a vowel bias. However, no significant results (nor bias) were found in preterm infants. The fact that no consonant or vowel bias was observed further supports the idea that with increasing complexity, preterm infants might face difficulties and process speech differently or atypically (Sansavini et al., 2011). The lack of effects found could also be due to the difficulty associated to the segmentation task itself, which required matching the word extracted during the familiarization to a similar but not same familiarized word. This line of research could be further investigated in longitudinal studies using brain techniques at different points in development.

Lastly, we investigated how prematurity and bilingualism may influence word segmentation abilities. Our preliminary results show that, taken together, preterm and fullterm bilingual infants successfully segment of monosyllabic words. However, the bilingual groups would need to be increased to have a more conclusive answer, given that the preterm group showed a marginal effect and had more participants than the fullterm group. Considering the sample size, it is still premature to draw any firm conclusions, but if this segmentation in 6-month-old balanced or French-dominant bilinguals was confirmed, together with the results showing segmentation in 4-month-olds, it would suggest that the syllabic unit has a special status from very early on that bootstraps segmentation even in bilingual infants who have had less exposure to the target language than their monolingual peers in the first half of the year.

In light of the attrition rates of the experiments in the present chapter, our results should be considered with caution. Rejection rates correspond to infants who did not finish the experiment due to failure to consistently turn their head. We found in Experiment 1 and 3 that these infants tended to have lower Apgar scores and longer hospital stays than those who successfully completed the experiment. This comparison suggests that included infants were in general more healthy and “high-functioning” than those excluded. Hence, our segmentation results might apply only to the healthiest preterm infants. We also observed that the rejection rate decreased with age, since fewer infants were rejected at 8 months than at 6 months, probably because their motor skills have also significantly developed by this age to allow proper turning to the blinking lights. Additional studies should be conducted either by presenting infants with front panels in the HPP procedure or by using other methods (eye-tracking, EEG, NIRS) to avoid the recruitment of motor skills and to allow testing

exclusively linguistic abilities. We will further discuss these issues in the General Discussion.

CHAPTER 2. Audiovisual Speech Perception

1. Experiment 6. Visual Scanning of a Talking Face in Preterm and Fullterm Infants

Typically, the speech input that infants receive from adult caregivers includes both visual and auditory information. Visual cues are often considered redundant with auditory cues, because both types of information are correlated with articulation. However, visual speech is still important for everyday speech perception. For example, seeing a talking face improves adult speech intelligibility even in clear listening conditions (Reisberg, McLean, & Goldfield, 1987), and developmental researchers have similarly shown that infants make use of visual speech cues when perceiving speech (Kuhl & Meltzoff, 1982; Bahrick, 1992). Currently, little is known about differences in audiovisual speech processing in preterm versus fullterm infants. In this chapter, I explore the hypothesis that prematurity might affect eye-gaze behavior when seeing talking faces due to the differential onset of auditory and visual learning in preterm, relative to fullterm, infants.

In the following, we first briefly review the literature on early visual perception and its development in preterm and fullterm infants. Then, we review work on infants' visual speech perception, and then focus on previous research on infants' visual scanning of talking faces, especially of the eye and mouth regions. A description of the experiment follows, which explores the visual scanning of a face talking in both the native and a non-native language as measured in preterm infants, as well as in fullterm infants matched for both postnatal and maturational age.

Visual perception development in infants

Unlike hearing, which is fully mature by the time a baby is born, vision is not fully developed (Boothe, Dobson, & Teller, 1985). This is partly because auditory information has been heard in the womb, while visual stimulation is minimal before birth (Querleu, et al., 1988). The ability to distinguish fine details, usually referred to as visual acuity, increases rapidly in the first year, reaching adult levels around 6 months in typically developing infants (Sokol, 1978). This developmental pattern likely occurs because the brain requires a certain degree of neural maturation and experience to process visual information. In a study comparing the visual acuity of preterm and fullterm infants at 6 months of postnatal age, Spierer, Royzman and Kuint (2004) found impaired binocular visual acuity in 53% of the preterm infants compared to 11% of the fullterm infants. These results seem to indicate that poorer visual acuity may be

attributed to immaturity of the visual system, although other research in the visual domain has shown that healthy preterms outperform their fullterm peers (Hunnus, Geuze, Zweens, & Bos, 2008; Ricci et al., 2008). Thus, the consequences of atypically early visual experience on a developing visual system still remain mixed.

Several studies have asked how visual development may be influenced by exposure using behavioral and electrophysiological techniques. Some evidence comes from studies on visual deprivation in infants who have been born with monocular or binocular cataracts (Maurer, Lewis, Brent, & Levin, 1999). After removal of the cataracts between the ages of 1 to 9 months, the visual acuity of these infants was at newborn levels. Although there is still a debate on the causes of this delay, this study demonstrates that visual input is necessary for visual functioning. Other research on preterm infants during the first months of life has revealed a more complex developmental pattern. For example, while visual and attentional development correspond to their postnatal age (Hunnus et al., 2008), smooth pursuit (i.e., the ability to track an object) is delayed with respect to fullterm infants at the same maturational age (Grönqvist, Brodd, & Rosander, 2011). These contrasting findings have been associated to the type of stimuli used (static/moving) and the development of underlying neural pathways. Additionally, the results of studies on visual development in preterm infants are still inconclusive because of the difficulty of assessing different gestational ages and low/high risk for health complications associated with vision (e.g. hypoxia). However, as suggested in the auditory-speech perception domain, it is possible that different constraints apply to different visual subdomains. Research in the visual development is still scarce, so future studies will broaden our knowledge of whether additional time in an extra-uterine environment can accelerate visual abilities.

Several questions arise about how early exposure to visual input might affect face perception, which is highly relevant for audiovisual speech perception. Work on face perception has shown that newborns prefer human faces and face-like stimuli to other configurations (Goren, Sarty, & Wu, 1975; Johnson, Dziurawiec, Ellis, & Morton, 1991) and attend more to faces that establish eye contact with them (Farroni, Csibra, Simion, & Johnson, 2002). They can also discriminate their mothers' face on the basis of external and internal features (eyes, nose, mouth) (Bushnell, 2001; Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995) and by 6 months they can recognize familiar faces on the basis of internal facial features (Rose, Jankowski, & Feldman, 2008). Besides, there is a perceptual specialization in linguistic development related to

visual information in the talking face. Evidence from a study at different ages in the first year has shown that 4- and 6-month-old monolingual infants can discriminate between a talking face speaking in a native and a non-native language in the absence of auditory cues, but 8-month-olds no longer perceive this difference. In contrast, 8-month-old bilingual infants continue to discriminate both languages visually (Weikum et al., 2007). Therefore, it seems that visual attention to facial cues contributes to linguistic development and that linguistic input shapes visual attention from very early on.

Furthermore, facial visual cues are important for communication and social abilities because they convey information about the emotional state (Buchan, Paré, & Munhall, 2007) or the focus of attention (e.g., gaze direction, Peña, et al., 2014). In the context of linguistic development, visual attention has also been related to the acquisition of lexical and semantic knowledge (Brooks & Meltzoff, 2005; 2008; Tomasello, 1995; Morales et al., 2000). However, until recently, very few experiments in the audiovisual literature have investigated to what extent preterm infants follow similar developmental patterns. Telford and colleagues (2016) showed that preterm infants at 7 months of maturational age exhibit consistently different looking patterns than fullterm infants in the presence of social stimuli. Relevant for the present study, the fullterm group looked longer to the eyes of a static face than the preterm group, suggesting that eye-gaze behavior in response to social content may be altered in preterm infants.

Given the lack of studies using eye-tracking as an instrument to investigate cognitive development in children at risk for later delays, the present study aims to contribute new data to audiovisual speech perception in preterm infants. In the following section, we will describe audiovisual speech processing in infancy, focusing on face perception and attention allocation in fullterm and preterm infants.

Audiovisual speech processing in infancy

Experiencing the overlapping streams of auditory and visual information is crucial to develop linguistic skills. From birth, infants prefer faces articulating normal speech over filtered speech and recognize speaking faces when lip-movements and sounds are presented simultaneously but not if speech is removed (Coulon, Guellai, &

Streri, 2011; Guellai, Coulon, & Streri, 2011). By 2 months, auditory perception of speech improves in the presence of visual cues (Hollich, Newman, & Jusczyk, 2005).

The detection of temporal synchrony of a face articulating speech and an accompanying voice has been studied from the first months of life (Dodd, 1979; Spelke & Cortelou, 1980; Walker, 1982). One common method is to present infants with auditory fluent speech and recording their looking time to synchronous or asynchronous visual speech (Bahrick, Hernandez-Reif, & Flom, 2005; Brookes, et al., 2001), or simply presenting infants with a vowel sound while they look at two faces silently articulating sounds, one of which matches the heard vowel (Kuhl & Meltzoff, 1982). These studies have revealed that matching performance depends on a number of factors, such as the paradigm and the type of stimuli used (e.g., native, non-native) as well as babbling characteristics and later language growth (Altvater-Mackensen & Grossman, 2015; Kuhl & Meltzoff, 1982, 1984, 1988; Patterson & Werker, 1999; 2002; Pons, Lewkowicz, Soto-Faraco, & Sebastián-Gallés., 2009; Streri, Coulon, Marie, & Yeung, 2016).

While the developmental trajectory of infants' audiovisual matching is well studied in typical populations, the exploration of these phenomena in infants at risk for later language delays remains limited. Some of the few studies on this issue have revealed that children with specific language impairment experience difficulties in detecting asynchrony and in integrating audio and visual information compared to typically developing infants (Pons, Andreu, Sanz-Torrent, Buil-Legaz, & Lewkowicz, 2013; Kaganovich, Schumaker, Leonard, Gustafson, & Macias, 2014). To our knowledge, only one study has addressed the ability to match the temporal cues of the speech available in the face and the voice in preterm infants relative to fullterm infants (Pickens, et al., 1994). The overall goal of the study was to assess the audiovisual matching of fluent speech at 3, 5 and 7 months in fullterm and preterm infants at the same maturational ages in order to detect possible delays in the group at risk. They were presented with side-by-side videos depicting two different female speakers while they listened to the auditory stream synchronized to one of them. Fullterm infants showed a U-shape performance, matching at 3 and 7 months but not at 5. In contrast, preterm infants did not show any preference for the synchronized face at any age. The authors suggest that preterms' failure to match audiovisually was not related to attentional deficits since the amount of total visual fixation to the videos did not differ between both populations. Instead, they suggest that prematurity appears to affect

audiovisual perception, as reflected by the attenuated matching abilities. Together, these reports suggest that temporal matching of audiovisual speech as a whole (in typical and atypical populations) is far more fragile than initial reports first suggested.

Since the ability to match audiovisual speech seems unstable during the first year of life, it is reasonable to think that matching performance might be related to developmental changes. In order to understand the possible relationship between infants' abilities and visual attention, a complementary line of research has begun to investigate visual scanning of talking faces (where infants look in the face) in development, which is taken as cues to underlying cognitive processes, especially in young infants. In the next section, we review some literature on face scanning patterns in the first year and its link to speech information in fullterm infants, before presenting our study on preterm infants.

Visual scanning of talking faces

The movements of a talking face provide a great deal of information. Not only is silent lip-reading possible (Bernstein et al., 2000; Summerfield, 1992) but it has been demonstrated that visual information of the face improves intelligibility (Reisberg et al., 1987). In the presence of noise, adults tend to lengthen the duration of gaze fixations on the mouth (Buchan et al., 2007; Vatikiotis-Bateson, Eigsti, Yano, & Munhall, 1998). In a similar way, adults also look more at the mouth when it is necessary to extract linguistic information in an unfamiliar language (Barenholtz, Mavica, & Lewkowicz, 2016). Other research shows that deaf people spend more time looking at the lower half of the face (Letourneau & Mitchell, 2011), which improves the ability to detect a change in the mouth region, than hearing individuals (McCullough & Emmorey, 1997). It appears that, under more difficult listening circumstances, when hearing is impaired or when specific speech processing is required, articulatory-visual cues in the mouth help adults improve their linguistic performance.

Developmental research has demonstrated that infants show age-related changes in visual scanning patterns of a talking face. Many studies have shown a developmental shift from eyes to mouth between 3.5 and 12 months in monolingual infants (Hunnius & Geuze, 2004; Lewkowicz & Hansen-Tift, 2012; Tenenbaum et al., 2013; Tomalski et al., 2013; Young et al., 2009). Interestingly, Young and colleagues (2009) found that 6-month-old infants who looked preferentially to the mouth of their

mother while she was talking had higher expressive language at the age of 24 months. These findings, together with the findings on adults, suggest that looking at the mouth might provide cues that support speech processing. Therefore, studying preterm infants' attention to visual cues while listening to speech during the first year can help us to better understand their developmental behavior.

The current study was motivated in large part by the results of Lewkowicz and Hansen-Tift (2012), who presented 4-, 6-, 8-, 10- and 12-month-old monolingual infants and adults with a video of female reciting a monologue. In Experiment 1, participants were presented with a video in their native language (English) and in Experiment 2 with a video in a non-native language (Spanish). For native speech, the main finding was that between 4 and 8 months, infants gradually shift away from the eyes to the mouth, but at the age of 12 months they start to shift back to the eyes. For non-native speech, infants present the same pattern as for native speech between 4 and 8 months; however, at 12 months they still look preferentially to the mouth. The first attentional shift towards the mouth between 4 and 8 months has been interpreted in link with the emergence of canonical babbling and with the fact that salient visual information might facilitate early speech perception and production abilities. Thus, this first shift suggests that seeing articulatory movement may modulate selective attention across development helping infants learn the linguistic properties of the language they are acquiring.

Interestingly, the second finding (i.e., the second attentional shift, towards the eyes, for native but not for non-native speech at 12 months) has been interpreted as the result of linguistic expertise. In other words, once infants have acquired enough experience with the native language, they may start paying attention to other communicative and social cues. As mentioned before, the eyes carry important social cues and are also useful to direct attention to an external object, which is involved in lexical development (Brooks & Meltzoff, 2005). This might explain why at the same age, when confronted with non-native speech, infants still rely on salient articulatory cues of the mouth. This pattern of preferential looking to the mouth has been found between 8-12 months in monolingual infants observing non-native speech (Kubicek et al., 2013). Moreover, attention to visual cues in audiovisual speech is modulated by linguistic background. Findings show that 4- and 12-month-old bilingual infants look longer to the mouth than monolinguals regardless of their familiarity with the language presented

(Pons, Bosch, & Lewkowicz, 2015). Accordingly, language input and expertise should modulate attention to visual cues.

Consistent with the idea that unfamiliar or unexpected audiovisual speech patterns might attract greater attention to the mouth in infancy, Tomalski et al. (2013) found longer looking times to the mouth for incongruent over congruent speech between 6 and 9 months. In addition, their results showed that infants discriminate congruent and incongruent audiovisual combinations of syllables on the basis of the total looking duration to the mouth. Furthermore, a recent EEG study has investigated the neural responses to congruent and incongruent AV speech between 6 and 9 months, the age at which the attentional shift has been found in monolingual eye-tracking data (e.g. Lewkowicz & Hansen-Tift, 2012; Pons et al., 2015). The authors of this EEG study found an association between the amplitude of the neural responses to incongruent speech and looking time to the mouth (Kushnerenko et al., 2013), which has been interpreted as a more mature electrophysiological response of AV processing. Taken together, these studies confirm Lewkowicz and Hansen-Tift's suggestion that infant's looking to the mouth during the second half of the first year of life reflects more mature linguistic processing of audiovisual speech.

While it has been argued that looking to the mouth may facilitate learning during phonological development, much remains to be explored in populations at risk for later linguistic abilities (ASD, SLI, preterm children). Broadening our knowledge about the factors that influence different looking behaviors will help us better understand the underlying processes of one of the most common human interactions, the audiovisual perception of the interlocutor. Therefore, the primary goal of this study was to examine the relationship between gaze patterns to the eyes and mouth in preterm infants.

The present study

A study comparing preterm and fullterm infants' audiovisual speech perception is important for several reasons. First, how preterm infants scan visual faces remains largely understudied. Second, the onset of visual and auditory stimulation in preterm infants follows a different timing compared to fullterm infants, given that preterm infants have earlier exposure to audiovisual perception than infants born at term (i.e., less auditory-only exposure to speech in utero). Third, the early postnatal environment of preterm infants differs greatly from that of fullterm newborns: For example, unlike

fullterm infants, a mother is rarely able to hold her preterm infant in her arms, within a short distance of her face. Moreover, fullterm infants are often raised in a quiet and comfortable environment with high quality linguistic input, but preterm infants (especially those born before 32 weeks) are often placed in an incubator in an intensive care environment with noise generated by medical devices around them (see Lahav & Skoe, 2014, for a detailed description of NICU environment), which may limit the quality of auditory exposure to language. These quantitative and qualitative factors might have critical implications for early linguistic development and visual processing.

In light of the recent findings on visual scanning of audiovisual speech and the above mentioned implications of prematurity on auditory and visual perception, an investigation comparing preterm and fullterm infants might provide valuable clues to early face perception patterns. In this study, we examine the effect of environmental input (i.e. exposure to unfiltered auditory and visual input after preterm birth) and brain maturation on face scanning abilities in order to better understand the mechanisms underlying the above mentioned developmental patterns. More specifically, we investigate the visual scanning patterns towards a face reciting a monologue at 8 months, the age at which fullterm infants are shifting their attention to a talking face towards the mouth (Lewkowicz & Hansen-Tift, 2012). Moreover, we also tested two groups of fullterm infants, one matched on postnatal age (8-month-olds), and another one at around their maturational age (6-month-olds) to control for developmental differences.

We used an eye-tracker while infants watched the video of a female French-English bilingual speaker telling a story in their native (French) and non-native (English) languages. As reported in previous studies on fullterm infants at these ages (Lewkowicz & Hansen-Tift, 2012), we expect fullterm infants to attend more to the mouth than to the eyes for the non-native language compared to the native language. Though the evidence on audiovisual perception in preterm infants is fairly limited, the current study offered the possibility to evaluate several hypotheses with regard to gaze behaviors. If preterm infants at 8 months of postnatal age are found to behave similarly to their 8-month-old fullterm peers, it would suggest that the development of audiovisual perception is driven by ex-utero experience and that preterm infants may develop typical audiovisual speech abilities from birth (as found in Hunnius et al., 2008, in the visual domain, or in Gonzalez-Gomez & Nazzi., 2012a, in the auditory speech perception domain). Alternatively, if preterm infants show similar scanning patterns as

fullterm 6-month-olds, it would suggest that neural maturation might constraint audiovisual perception abilities despite early exposure to simultaneous audiovisual speech.

A third possibility is that, in addition to immaturity, poorer quality of audiovisual exposure due to the stay in intensive care may lead to the development of atypical attentional processes in preterm infants that would differ both from fullterm infants of equivalent postnatal (8 months) and maturational age (6 months). This is based on studies in social cognition showing different looking behavior from their fullterm peers even when matched for maturational age (Telford et al., 2016) and on audiovisual speech perception studies failing to find detection of synchronous visual and auditory streams during the first year (Pickens et al., 1994). A likely possibility, therefore, is that preterm birth is associated with difficulties in speech processing or with alterations in visual scanning of a talking face reflected in global differences in eye and mouth scanning compared to what is found in fullterm infants.

METHOD

Participants

Twenty-two healthy preterm infants (mean postnatal age = 8 months and 18 days, $SD = 8.4$; mean maturational age = 7 months and 2 days; 12 females) were tested. In the group of preterm infants, eight were born at < 32 wGA (mean = 29.7; $SD = 0.74$) and fourteen were born ≥ 32 wGA (mean = 35.3; $SD = 1.27$, see Table 2.1 for neonatal characteristics). Twenty-four healthy fullterm 6-month-old infants (mean = 6 months and 15 days, $SD = 6.6$; 12 females) and twenty-four healthy fullterm 8-month-old infants (mean = 8 months and 17 days, $SD = 8.1$; 11 females) also took part in the eye-tracking study. All parents gave informed consent before participation. The inclusion criteria were being monolingual (more than 80% of input in French), with no reported hearing or serious health problem (brain injury, long retinopathy, or surgical intervention). Language background and health was assessed through parental interview and the child's health booklet. Infants did not follow any stimulation/intervention programs.

Table 2.1. Neonatal characteristics of the participants.

| | Mean (SD) | Range |
|--------------------------|------------|----------|
| Neonatal History | | |
| Gestational age (wk) | 33.3 (3.0) | 28-36 |
| EPT (<28 wks, $n = 0$) | | |
| VPT (28<32, $n = 8$) | | |
| MPT (32<34, $n = 2$) | | |
| LPT (34<37, $n = 12$) | | |
| Birth weight (g) | 1803 (582) | 609-2900 |
| Stay in hospital (days)* | 41. (29.0) | 6-103 |

*Information for five LPT infants not available.

Additional infants were tested but excluded for several reasons in the 8-month-old fullterm group: bad calibration of the eyes (2), total looking time below one third of the experimental time (1). All 6-month-old fullterm and 8-month-old preterm infants completed the experiment.

Stimuli

Two video clips were recorded in French (native language of the participants) and in English (a non-native language) by a French-English native-like bilingual female speaker reciting a typical child story (“the three little pigs”) in a child-directed manner against a black background (for transcriptions of the monologue, see Appendix 4). We used the same speaker to make sure that infants’ looking preferences could only be guided by linguistic stimuli and not by differences in facial features between different speakers. Each video was edited to start with the beginning of the story telling and end after 45 seconds (same duration as in Lewkowicz & Hansen-Tift, 2012, and Pons et al., 2015). Videos were captured at a rate of 24 frames per second. The sound was presented at 65 dB for both videos.

Procedure

Participants were seated on a parent’s lap in a dimly lit room in front of a Tobii T60 eye-tracker monitor (1280 x 1024 pixels), at an approximate distance of 60 cm. The testing session began with a five-point calibration sequence. Calibration was followed by a video of a colorful bouncing ball to attract infant’s attention to the center of the screen. It was followed by the sequential presentation of the two videos. A colorful animation was played between the two videos to re-attract infants’ attention

to the center of the screen. The entire test lasted less than 5 minutes. Order of presentation of the two languages was counterbalanced across infants.

In addition, a babbling questionnaire was filled out by the parents after the video session to compare babbling abilities between preterm and fullterm groups (adapted from Gonzalez-Gomez & Nazzi, 2012a). The questionnaire distinguished two levels of babbling production. Level 1 included native vowel production (/a/, /e/, /eu/, /i/, /o/, /ou/, /u/) and Level 2 included syllable production: repetition of same syllables (e.g. /yaya/, /baba/), or production of different concatenated syllables (e.g. /bada/, /badi/). The questionnaire had a total of 11 items (see Appendix 5).

Data Analysis

Two types of analysis were performed. First, an AOI approach was used to explore visual attention in the different groups. Two AOIs were considered: eyes and mouth (see Figure 2.1). The AOIs were drawn around the eyes and mouth, making sure that both regions had the same size and that the eyes and mouth were inside the AOIs during the entire duration of the monologues despite the natural movements of the speaker. The Tobii Studio software package was used to calculate the sum of fixations of each participant to each AOI. The proportion of total looking time (PTLT) was computed by dividing the fixation on one AOI (i.e., eyes or mouth) by the amount of total looking time (to the screen). Next, an Eyes-Mouth Index was calculated: (looking time to the eyes - looking time to the mouth) / looking time to the screen. These measures were calculated for each monologue and for each infant.



Figure 2.1. Scene capture of the video, showing the size of the eyes and mouth areas of interest (AOIs).

Second, a data-driven approach was performed using iMap Matlab toolbox (Caldara & Millet, 2011) to investigate the spatial distribution of fixations. The iMap toolbox computes statistical maps of fixations by computing fixation distributions across the duration of the experiment, smoothing them with a Gaussian kernel, generating 3D maps. Each individual smoothed fixation map is Z-scored in the space (1280 x 1024) to represent the individual fixation bias. Fixation maps were calculated for each group and each language. Since these analyses have only been recently used (Liu et al., 2015; Shi et al., 2015) and are still not standardized, the iMaps are only provided in Appendix 6 for visualization.

RESULTS

Total looking time

The first analysis asked whether there were group differences in global levels of visual attention. Hence, we conducted a one-way ANOVA with PTLTs to the whole screen as the dependent variable and group (8-month-old preterms, 8-month-old fullterms, 6-month-old fullterms) as fixed factor. This analysis failed to show differences in total looking time between groups $F(2, 67) = 2.26, p = .11, \eta_p^2 = .063$ (see Figure 2.2). Since there were no differences in the total looking times, we proceeded to analyze proportional fixation to the mouth and eyes AOIs.

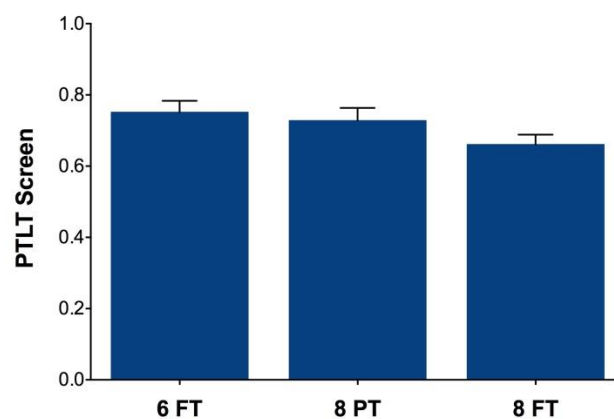


Figure 2.2. Proportion of total looking time to screen for the 3 groups (6FT = 6-month-old fullterms; 8PT = 8-month-old preterms; 8FT = 8-month-old fullterms). Bars indicate standard error.

Proportional Fixation Duration for AOIs: Eyes and Mouth

As the dependent variable, we used for each infant the Eyes-Mouth Index. To analyze whether the groups showed different looking patterns, we computed a one-way repeated measures ANOVA with “Language” (native *vs.* non-native) as within-subjects factor and “Group” (8-month-old preterms, 8-month-old fullterms, 6-month-old fullterms) and “Order” of language presentation (Native first, Nonnative first) as between-subjects factors. The ANOVA revealed a significant main effect of Language ($F(1, 64) = 12.01$, $p = .001$, $\eta_p^2 = .158$), indicating that the time spent looking at the eyes relative to the mouth was higher for the native language ($M = .20$, $SD = .53$) than for the non-native language ($M = .09$, $SD = .53$). The analysis also yielded a significant Language x Group interaction ($F(1, 64) = 4.10$, $p = .02$, $\eta_p^2 = .113$), indicating that attention to the mouth and the eyes varied as a function of the language and the group (see Figure 2.3). All other effects were non-significant, including the effect of Order ($F(1, 64) = .253$, $p = .62$, $\eta_p^2 = .004$), Group ($F(2, 64) = .295$, $p = .75$, $\eta_p^2 = .009$), Order x Group ($F(2, 64) = 1.62$, $p = .21$, $\eta_p^2 = .048$), Language x Order ($F(1, 64) = 1.73$, $p = .19$, $\eta_p^2 = .026$), and Language x Group x Order ($F(1, 64) = 1.43$, $p = .246$, $\eta_p^2 = .043$).

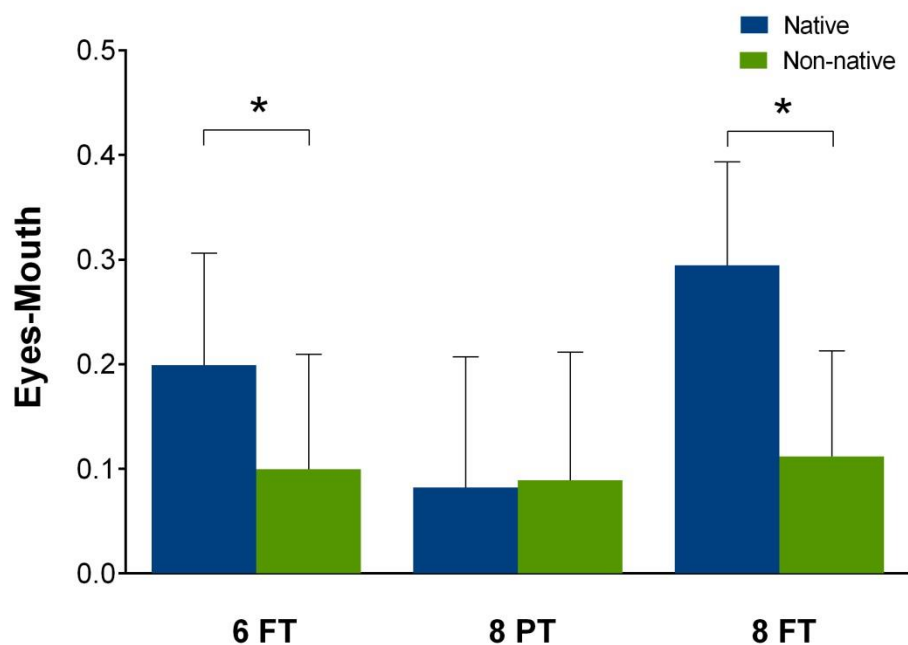


Figure 2.3. Eyes-Mouth index based on proportions on looking times for each group (from left to right: 6-month-old fullterm, 8-month-old preterm, 8-month-old fullterm) and for each language. Bars represent error bars. * = $p < .05$.

To determine the source of the Language x Group interaction, we conducted paired t-tests with the Eyes-Mouth Index as the dependent variable in the native and non-native conditions. For the preterm 8-month-olds, there was no significant difference between the time they spent looking to the eyes relative to the mouth between the native ($M = .08$, $SD = .59$) and non-native ($M = .09$, $SD = .57$) languages; $t(21) = -.11$, $p = .91$. However, the difference between the native ($M = .20$, $SD = .52$) and the non-native language ($M = .09$, $SD = .54$) was significant in the group of fullterm 6-month-olds, $t(23) = 2.43$, $p = .023$. The difference between the native ($M = .29$, $SD = .49$) and the non-native language ($M = .11$, $SD = .49$) was also significant in the group of fullterm 8-month-olds, $t(23) = 3.59$, $p = .002$. Note that the differences in the fullterm groups remain significant when applying the Holm-Bonferroni method to correct for multiple comparisons (critical p-values for the 3 comparisons being $p = .02$, $p = .03$, and $p = .05$).

To explore the potential effect of degree of prematurity, we performed a repeated measures ANOVA for the preterm group using the Eyes-Mouth index as dependent variable, Language (native vs. non-native) as within-subjects factor, and Degree (N=8 very preterm, N=14 moderate/late preterm) and Order of presentation (Native first, Nonnative first) as between-subjects factors. The ANOVA revealed no significant main effect of Degree, $F(1, 18) = .10$, $p = .33$, $\eta_p^2 = .053$. All the other main effects and interactions also failed to reach significance.

Additionally, we considered degree of prematurity as a continuous variable, and ran correlations between the Eyes-Mouth index for each language and gestational age and birth weight. All *Pearson* (unilateral) correlations failed to reach significance for the native language (gestational age: $r = -0.21$; $p = .46$; birth weight: $r = -0.28$; $p = .11$) and the non-native language (gestational age: $r = -0.18$; $p = .22$; birth weight: $r = -0.30$; $p = .09$).

Babbling levels

To assess possible developmental differences in communicative abilities, we compared babbling levels between the three groups. A one-way ANOVA was performed with total babbling score as a dependent variable and group (8-month-old preterms, 8-month-old fullterms, 6-month-old fullterms) as fixed factor. The results showed no significant effect of group $F(1, 67) = .951$, $p = .39$, $\eta_p^2 = .028$. Mean babbling score was

3.8 ($SD = 1.3$) for the 8-month-old preterms, 3.3 ($SD = 1.2$) for the 6-month-old fullterms and 3.8 ($SD = 1.7$) for the 8-month-old fullterms.

DISCUSSION

The present study aimed at exploring the contribution of experience and brain maturation to face scanning patterns when processing audiovisual speech in the native and non-native language in development. It examined similarities and differences in gaze behaviors between a group of preterm infants and two groups of fullterm infants who were matched on postnatal and maturational ages. Our findings identified differences between both populations in the proportion of looking to the eyes and the mouth depending on the language familiarity. While 6- and 8-month-old fullterm infants fixated longer the speaker's mouth for the non-native language compared to the native language, preterm infants looked equally to the eyes and the mouth for both languages. Furthermore, the differences found between the preterm and fullterm groups were not related to overall differences in visual attention and babbling levels. In our small sample, degree of prematurity was not associated to looking behavior, but this question will need to be further investigated in the future. We will discuss the findings for each population in turn, starting with the fullterms.

Factors modulating attention to the eyes and the mouth in fullterm infants

Regarding the fullterm groups, our findings partly replicate, and partly differ, from previous reports in the literature. Our first finding, showing more attention to the eyes relative to the mouth for the native than for the non-native language, indicates that infants discriminated audiovisually their native language from a non-native language, and can be taken as indication of successful speech processing. It is congruent with previous literature showing that 6- to 12-month-old monolinguals look more to the mouth (relative to the eyes) when observing non-native speech (relative to native speech). This brings further support to the suggestion that when the task is cognitively more demanding, articulatory cues might support speech processing (Lewkowicz & Hansen-Tift, 2012; Kubicek et al, 2013). This interpretation is also consistent with evidence showing that infants fixate more the mouth for incongruent than congruent stimuli (Tomalski et al, 2013). Likewise, it is in line with adults' behavior that also look preferentially to the mouth when normal hearing is distorted (Buchan et al., 2007; Letourneau & Mitchell, 2011) or when the task requires extracting linguistic

information (Barenholtz et al., 2016). Thus, our results regarding the fullterm group support previous evidence on monolingual populations suggesting that language familiarity modulates attention to facial cues.

However, in terms of development, our results are in contrast with previously reported gaze patterns showing a gradual decrease of interest in the eyes and a shift towards the mouth between 6 and 8 months (e.g., Lewkowicz & Hansen Tift, 2012). What could explain the different pattern that we observed? One of the explanations could be experimental differences, in particular, in stimuli conception and design. The videos used in the present experiment were recorded in a child-directed manner, in contrast with previous studies that have used infant-directed speech (e.g., Lewkowicz & Hansen-Tift, 2012; Pons et al., 2015). Impressionistically, our sample of child-directed speech contains faster speech rate as well as more naturalistic eye and head movements than stimuli used in the previous studies (precise analyses will need to be concluded). Given the report by Lewkowicz and Hansen-Tift (2012) that infants display increased looking to the eyes in adult-directed speech than in infant-directed speech, the differences in findings could indicate that infants pay more attention to the eyes when there is more movement in the upper part of the face, which also conveys relevant communicative information (Buchan et al., 2007).

Lastly, the differences observed between our study and the literature could be related to the native language of the participants. It is possible that different looking patterns are observed depending on the characteristics of the language, hence that face scanning while processing audiovisual stimuli becomes language-specific as infants learn properties of their native language. More specifically here, it could be that the fact that French does not have lexical stress, while English, Catalan and Spanish (the native languages of the infants in Lewkowicz & Hansen Tift, 2012; Pons et al., 2015) do, leads to different gaze patterns, as it has been found to lead to differences in auditory processing of lexical stress (Höhle et al., 2009; Skoruppa et al., 2009; Bijeljac-Babic et al., 2012). Given the few languages in which this issue has been explored so far, more crosslinguistic studies will be necessary to further explore this possibility.

Preterm infants' scanning patterns

One of the main results showed that preterm infants had similar gaze patterns for the native and non-native language, while their fullterm controls looked more at the eyes than the mouth for the native language compared to the non-native language. A

first explanation of this difference relates to the more premature developmental stage of the preterm visual system. Previous research in the visual domain has demonstrated that preterm infants present a larger proportion of acuity deficits (Spierer et al., 2004) and some delays in the development of smooth pursuit with respect to fullterm infants (Grönqvist et al., 2011). Thus, it is possible that the similar looking patterns to both languages found in the preterm group are related to how premature visual exposure might affect the visual system. Although no retinopathy or visual deficits were reported for the infants included in the present study, much remains still unknown about how early exposure to a visual environment might affect an immature organism.

Another possible explanation is that the differential onset of visual and auditory perception in preterm infants affects the integration of both systems. Some researchers have argued that the reason why some sensory systems (e.g. auditory) are functional and receive input before other systems (e.g. visual) may be to decrease competition between the developing sensory systems, likely reducing the complexity of the information to be processed (Turkewitz & Kenny, 1982, 1985). In contrast, the fact that the organism of preterm infants receives earlier input from the extrauterine audiovisual environment may increase competition between the auditory and visual systems at an earlier developmental stage. As a consequence, audiovisual integration might not follow the typical developmental trajectory. This idea may be supported by preterm infants' failure to detect temporal cues in audiovisual speech during the first year (Pickens et al., 1993).

Yet another possibility is that preterm infants' looking patterns are associated with general difficulties in processing perceptual stimuli. For example, previous evidence has demonstrated that fullterm infants prefer to look at the mouth for perceptually incongruent over perceptually congruent stimuli (Tomalski et al., 2013), and similar looking patterns have been reported in adults under difficult hearing circumstances, such as speech in noise or hearing impairment (Buchan et al., 2007; Letourneau & Mitchell, 2011; Vatikiotis-Bateson et al., 1998). In bilingual populations, increased attention to the mouth has been associated to the dual challenge of processing two languages and keeping them apart (Pons et al., 2015). Therefore, we argue that, similarly to what is found in monolingual individuals under difficult hearing circumstances or bilingual infants that probably find the mouth region highly informative, preterm infants may fixate less the eyes in order to benefit from salient articulatory visual cues onto speech perception. Unlike the second explanation above,

the present explanation points to more general perceptual difficulties, rather than specific difficulties in audiovisual integration.

A fourth possibility is that the perceptual experiences of preterm infants differ from that of fullterm infants. For example, social aspects of early life experiences may play a role in the development of audiovisual speech perception. As mentioned before, many preterm infants grow up in a particular environment in the first months of life, characterized by less social interactions and the noises of medical devices around them (Lahav & Skoe, 2014). The medical environment and the nature of the interactions with their caregivers in this context could have an impact not only on speech perception but also on social abilities. Recent evidence demonstrated that, when presented with the image of a face, preterm infants at 7 months of maturational age exhibit shorter looking times to the eyes than fullterm infants (Telford et al., 2016). How the particular circumstances of these babies placed in a noisy intensive care unit, together with the neurodevelopmental immaturity, combine to form detrimental conditions for audiovisual speech perception will require further investigation.

Given that few studies have investigated audiovisual perception in preterm infants in the first year of life (Perszyk et al., 2016; Pickens et al., 1994), it is difficult at this point to ascertain whether the stage of development of the visual system, the integration of auditory and visual systems, speech perception difficulties or environmental factors can explain the atypical developmental pattern in infants born prematurely observed in this task. Note that these possibilities are not mutually exclusive. Moreover, although our analyses (ANOVA and correlations) did not reveal a link between looking patterns and degree of prematurity, our small sample does not allow us to conclude the absence of a link either. Of note, our results indicate that differential looking patterns are found even in a group of infants including a larger number of moderate and late preterm than extremely and very preterm infants. Further assessment of audiovisual speech perception in larger groups of extremely-to-late preterm infants will help to elucidate the questions raised above. The fact remains that the differential gaze patterns reported here between the preterm and fullterm populations provide a first step to characterize the developmental course of preterm infants.

Limitations

Several limitations of the present study need to be addressed. First, the study lacks a balance between the number of extremely/very preterm infants and moderate/late preterm infants, which would allow to better explore how degree of prematurity modulates gaze allocation to facial features in the presence of native and non-native speech. Future longitudinal research should further investigate the link between early audiovisual perception and later linguistic skills in this population. It is important to highlight the fact that a number of studies comparing preterm children with fullterm controls have demonstrated that preterm children have higher rates of language problems and visual-perceptual deficits (Aylward, 2002; Barre et al., 201; Sommerfelt, Markestad, & Ellertsen, 1998). Second, “child-directed-speech” might be less suitable than “infant-directed-speech” to test infants in the first year of life because it might correspond less to the type of speech they are used to hear when being directly addressed. Third, the use of the same person for both monologues, while controlling for idiosyncratic visual preferences, may be detrimental for keeping infants’ attention throughout the experiment, as we observed a tendency to decrease attention, especially in the group of 8-month-old fullterm infants. Nevertheless, the difference between groups did not reach significance. Therefore, future studies should use more speakers (if possible, more than one for each language to avoid preference for facial features not related to speech processing). To sum up, the gaze behavior assessed here provides a first step to track the profile of gaze behavior in the presence of a talking face in preterm and fullterm infants.

Summary and future directions

Concerning fullterm infants, our data show that infants fixate more the eyes relative to the mouth for the native language compared to the non-native language. These results support previous evidence suggesting that allocating more time on the eyes as linguistic skills improve in development and more to the mouth in the presence of unfamiliar speech.

Compared to fullterm infants matched on similar postnatal and maturational ages who show different scanning pattern of a face speaking in the native and non-native language, preterm infants at 8 months postnatal age show similar scanning patterns for both languages. In particular, they looked proportionally less to the eyes relative to the mouth for the native language than 6- and 8-month-old fullterm infants.

The similar looking pattern in preterm infants probably signals the effect of their particular early life circumstances: visual input on an immature organism, differential onset of visual and auditory extrauterine exposure with respect to typical development (and consequently need for earlier integration of both sensory systems), and early medical and social environments. Such effects (which will have to be further specified) were found in the present study even though these circumstances may affect infants born earlier in gestation (extremely and very preterm) to a larger extent, and our study included a larger number of moderate/late preterm infants. Future research should focus on determining the role of the degree of prematurity in the scanning patterns of a talking face in development. Considering that much of the daily communication involves face-to-face interactions, it is crucial to understand the underlying cognitive mechanisms involved in audiovisual speech perception to set up future, efficient intervention strategies.

CHAPTER 3. Word-form Recognition and Word Production

Throughout childhood, different measures of language assessment (e.g. parental reports, MCDI, standardized clinical tests like the Bayley), usually reveal that children born preterm perform below their fullterm counterparts in lexical comprehension (Caravale et al., 2005; Saavalainen et al., 2006) and lexical production (Foster-Cohen et al., 2007; Gayraud & Kern, 2007; Saavalainen et al., 2006; Sansavini et al., 2011). Importantly, a recent meta-analysis revealed that the more complex the language function the more difficulties former preterm infants encounter (van Noort-van der Spek et al., 2011). Despite the breadth of research carried out during childhood in this population, exploration of early lexical abilities before the second year of life remains limited. In this chapter, we focus on early word (i.e. word-form) recognition and vocabulary production. We ask whether and to what extent preterm infants differ from fullterm infants. A second goal of the present chapter is to examine the appropriateness of postnatal age in the second year of life for language assessment.

1. Experiment 7. Word-form recognition at 11 months postnatal age

By the time infants produce their first words, -mommy, daddy, ball-, they have built a good deal of linguistic perceptual abilities. Word learning involves recognizing the sound forms of the words from the flow of speech, discovering their conceptual units, mapping them appropriately and retaining these components in memory (Waxman, 2003). When this process is achieved, it is considered that word comprehension takes place. However, infants often recognize words, or rather word-forms, before attaching meaning to them or knowing their exact phonological structure (Hallé and de Boysson-Bardies, 1994).

Although much of the mechanisms involved in word-form recognition remain unclear, there is evidence for early links between listening in natural settings and recognition in 4-5-month-old infants: they can recognize the sound pattern of their own name (Mandel et al., 1995) even when some phonetic information (the onset consonant) is replaced in French-learning infants (Bouchon et al., 2015; though a different pattern is found for English-learning infants; Delle-Luche et al., 2017). Around the age of 6 months, infants show early comprehension of some familiar words when presented with audio and visual stimuli. For example, they can associate the words “mommy” or “daddy” presented auditorily with their appropriate image (Tincoff & Jusczyk, 1999). They can also link body part nouns such as “hands” or “feet” and other very frequent words to their visual referents (Bergelson & Swingley, 2012; Tincoff & Jusczyk, 2012). These studies suggest that very young infants not only recognize (a few) very common word-forms from their everyday life but that they can also map them to their referents from very early on in development. This might be related to young infants’ ability to quickly associate sounds and objects as has been demonstrated in the laboratory for the association between a syllable and a moving object from 7 months of age (Gogate & Bahrick, 2001).

Additional research has considered whether highly familiar words might confer an advantage in word segmentation. Bortfeld and colleagues (2005) documented that 6-month-old English-learning infants segmented words when placed next to familiar words (e.g., mommy or their own name) in the speech stream (for similar results at 8 months in French, see Mersad & Nazzi, 2012). The effect of familiarity has been further assessed by testing whether infants are able to segment words that sound similar to familiar ones (Altvater-Mackensen & Mani, 2013). German-learning 7-month-olds were

first familiarized with a passage containing CVCV words and then tested with similar-sounding novel words or phonetically unrelated words. Infants segmented more easily the similar-sounding words, indicating that word-form familiarity might bootstrap lexical acquisition. These results point to a potential powerful effect of familiar words in lexical acquisition, which further highlights the importance of studying the effect of word familiarity in preterm infants between 6 and 12 months, a crucial period in which segmentation abilities and word-form recognition emerge in fullterm infants.

Evidence for word recognition in the second half of the first year has demonstrated that words are progressively better recognized. As in the segmentation studies described above, the effects of familiarity have been explored in word recognition by either training infants with familiar words or by testing them based on their previous knowledge. For instance, 8-month-old infants have stored in memory word forms after been familiarized with them for ten days over two weeks (Jusczyk & Hohne, 1997). Without training, evidence for a *protolexicon* has also been found at 11 months. The first study on this issue, by Hallé and de Boysson-Bardies (1994), showed that French-learning infants prefer to listen to familiar words such as *biberon* ('baby-bottle') than to infrequent words in infant directed speech, such as *busard* ('harrier'). At this age, French-learning infants also prefer familiar bisyllabic words (e.g. *gateau* 'cake') over pseudowords made up with the first syllable of the familiar word and another syllable made up with a consonant and a vowel taken from the list of familiar words (e.g. *gazi*; Poltrock & Nazzi, 2015). English-learning 9-month-olds fail to recognize the difference between familiar bisyllabic lexical items and 'misstressed' (e.g. /baBY/ instead of /BABy/) or 'mispronounced' (e.g. "nirty" instead of "dirty") stimuli but they succeed at 11 months (Vihman, et al., 2004). Dutch-learning 11-month-olds prefer a list of animal words and body part words over a list of nonwords (Swingley, 2005). Thus, it seems that at the age of 11 months infants reliably show word-form recognition of familiar words in several languages. Interestingly though, Ngon et al. (2013) demonstrated that 11-month-old French-learning infants recognize syllable pairs that are highly frequent in the input (which could either be words or nonwords), supporting the idea that infants rely on statistical information for distinguishing potential candidate words from non-candidate words. Together, these results suggest that during the second half of the first year infants have compiled word knowledge likely based on

prosodic, phonetic and statistical information from their everyday communication with their caregivers, allowing them to gradually add new words to their vocabulary.

Further, during the second and third year, word comprehension has been tested using the looking while listening paradigm (LWL). This method presents infants with two images while it measures the amount of looking time to the right object in response to its spoken label (Fernald et al., 2008). This method allows to assess word comprehension through both accuracy and speed of recognition of the responses (Fernald et al., 2006). In preterm toddlers, the few studies to our knowledge that have investigated early word recognition using the LWL paradigm have revealed three main findings. First, very preterm toddlers' comprehension and efficiency is more similar to fullterm infants at the same maturational rather than postnatal age (Loi et al., 2017). Second, even if accuracy levels are above chance at postnatal age, poorer processing speed measures were found in very preterms with respect to fullterms (Marchman et al., 2016; Ramon-Casas et al., 2013). Third, processing efficiency (reflected by both reaction time and accuracy) has been associated to higher vocabulary scores at 36 months. Noteworthy, individual variation in accuracy and reaction time in the LWL task was a more robust predictor of later language outcomes in the standardized test than preterm-fullterm group differences (Marchman et al., 2015). It is important to highlight this latter point because Bayley Scales of Infant Development are often the primary diagnostic tool to consider eligibility for early intervention (Gauthier, Bauer, Messinger, & Cloisius, 1999).

Given the growing number of studies reporting persistent lexical delays from the second year of maturational age in preterms using standardized language assessment (refs), the purpose of Experiment 7 was to investigate whether preterm infants recognize familiar word-forms at the same postnatal age as their fullterm peers or whether they show some delays in early recognition. In order to explore this issue, we chose Poltrock and Nazzi (2015) baseline experiment and used HPP to present preterm infants with a list of familiar words and a list of pseudowords. Due to recruitment constraints, our sample includes a greater number of moderate and late preterm infants than extremely and very preterm infants. According to the results of Chapter 1 of the present dissertation showing that preterm infants present some basic segmentation skills at 6 months postnatal age, an essential ability for lexical

acquisition, it is possible that by the end of the first year they will be able to recognize some familiar word-forms.

METHOD

Participants

The participants were twenty preterm infants (10 females and 10 males), with a mean postnatal age of 11 months and 18 days (range: 11 months and 4 days to 12 months and 2 days). Of the twenty infants, 3 were very preterm infants (mean GWs = 28.9 weeks, $SD = 0.38$, range: 28-29) and 17 were moderate and late preterm infants (mean GWs = 34.5 weeks, $SD = 1.15$, range: 32-35; see Table 3.1. for neonatal characteristics). The sample included families with a large range of socioeconomic status (although this information was not collected). All parents gave informed consent before participation. The inclusion criteria were being monolingual (more than 80% of input in French), with no reported hearing or serious health problem (brain injury, long retinopathy, or surgical intervention). Language background and health was assessed through parental interview, the child's health booklet and, for infants recruited at the hospital, the hospital records. Infants did not follow any stimulation/intervention programs. Three additional infants were not included in the experiment due to inattentiveness (1), parental interference (1) and segmentation index more than 2 SD above or below the group mean (1). All infants were recruited via i) a hospital (Hôpital Robert Debré, Paris) or ii) regular laboratory recruiting through the birth lists issued by the Paris city registry office.

Table 3.1. Neonatal characteristics of preterm infants.

| | Mean (SD) | Range |
|--------------------------|-------------|-------------|
| Neonatal History | | |
| Gestational age (wk) | 33.6 (2.3) | 28-36 |
| VPT (28<32) ($n = 3$) | | |
| MPT (32<34) ($n = 4$) | | |
| LPT (34<37) ($n = 13$) | | |
| Birth weight (g) | 1.965 (490) | 1.120-2.620 |
| Stay in hospital (days) | 27.6 (22.0) | 5-91 |

Stimuli

The stimuli used were those used in Experiment 1 of Poltrock and Nazzi (2015). Ten disyllabic CVCV words were chosen as familiar test words from the French version of the CDI (Kern, 2003). The pseudowords consisted of ten CVCV disyllables that were constructed by combining the first syllables of each familiar word (e.g., the [ga] of *gâteau* ‘cake’) with a new syllable obtained by recombining some of the consonants and vowels of the second syllables of the familiar words. The list of familiar words and pseudowords are given in Table 3.2.

Table 3.2. Test stimuli used in Experiment 8: Familiar words versus pseudowords (from Poltrock & Nazzi., 2015).

| Familiar word | Phonetic transcription | English translation | Pseudoword |
|----------------|------------------------|---------------------|------------|
| <i>gâteau</i> | /gato/ | cake | /gali/ |
| <i>lapin</i> | /lapɛ̃/ | rabbit | /lato/ |
| <i>poupée</i> | /pupe/ | doll | /puzø/ |
| <i>ballon</i> | /balɔ̃/ | ball | /bavu/ |
| <i>chapeau</i> | /ʃapo/ | hat | /ʃate/ |
| <i>oiseau</i> | /wazo/ | bird | /walø/ |
| <i>maison</i> | /mɛzɔ̃/ | home | /mɛpi/ |
| <i>bisou</i> | /bizu/ | kiss | /bido/ |
| <i>body</i> | /bodi/ | body | /bove/ |
| <i>cheveux</i> | /ʃøvø/ | hair | /ʃødu/ |

The stimuli were recorded in a sound-attenuating booth, using an Audio-Technica ATR-20 microphone, by a French female native speaker in an infant-directed manner. They were digitalized using a 16-bit resolution and 44.1-kHz sampling rate (Cool Edit Pro software). Three tokens of each item were selected. Six pseudo-randomized lists were constructed for each condition (six “familiar words lists” and six “pseudowords lists”). In each list, the 10 pseudowords were presented twice, in two different “blocks” using different tokens of each item in the two blocks. The order of the items was pseudo-randomized, making sure that the position of occurrence of each pseudoword was well distributed within and across lists. All lists were 23.25 s in duration, with an interstimulus interval varying between 582 and 600 ms. To ensure that looking times were not due to acoustic differences between the familiar words and

the pseudowords, acoustic analyses were performed on word duration, intensity, and fundamental frequency measures (mean, minimum, and maximum F0). Means, standard deviations, *t* values, and levels of significance are given in Table 3.3. No significant acoustic differences were found between the familiar words and the pseudowords.

Table 3.3. Acoustic characteristics of the stimuli in Experiment 1 (SDs in brackets, from Nazzi & Poltrock, 2015).

| | Condition | | <i>t</i> value, significance level (two sided) |
|--------------------|------------|-------------|--|
| | Familiar | Pseudowords | |
| Duration (ms) | 601 (45) | 593 (45) | $t(18) = 0.36, p = .72$ |
| Amplitude RMS (dB) | 69.8 (5.3) | 71.1 (4.7) | $t(18) = -0.58, p = .57$ |
| F0 mean (Hz) | 220 (18) | 222 (9.5) | $t(18) = -0.31, p = .76$ |
| F0 min (Hz) | 162 (23) | 160 (11) | $t(18) = 0.16, p = .87$ |
| F0 max (Hz) | 316 (18) | 320 (38) | $t(18) = -0.32, p = .75$ |

Procedure, apparatus and design

The experiment was conducted in a sound-attenuated booth, which contained a three-sided test booth made of pegboard panels. The test booth had a red light and a loudspeaker (Sony xs-F1722) mounted on each of the side panels and a green light mounted on the central panel. A video camera was situated directly below the center light to monitor infants' behavior (although for ethical reasons, the videos could not be saved, and coding was done online). A PC computer terminal (Dell Optilex), audio amplifier (Marantz PM4000), TV screen, and response box were located outside the sound-attenuated room.

The procedure was identical to that used in baseline Experiment 1 of Poltrock and Nazzi (2015). Each infant was held on a caregiver's lap and the caregiver was seated in a chair at the center of the test booth. Each trial began with the green light on the center panel blinking until the infant had oriented in that direction. Then the center light was extinguished and the red light above the loudspeaker on one of the side panels began to flash. When the infant had made a headturn bringing their head direction within 30° from the light/loudspeaker, the stimulus for that trial was played (the red light continuing to flash for the entire duration of the trial). Each stimulus was played to completion or stopped immediately after the infant failed to maintain the 30°

headturn for 2 s. If the infant turned away from the red light for less than 2 s and then turned back again, the trial continued but the time spent looking away was not included in the orientation time (OT). If the infant's initial OT was shorter than 1.5 s on a given trial, the trial was immediately replayed from the beginning and the initial OT was discarded.

The experimental session began with two musical trials, one on each side (randomly ordered) to give infants the opportunity to learn the contingency of their headturn and the stimulus presentation. The following test phase consisted of twelve trials, six of each condition (words and pseudowords lists). The side of the loudspeaker from which the stimuli were presented randomly varied from trial to trial (for each condition: three trials on the left side, three trials on the right side) and the order of the different lists was pseudo-randomized with no more than two trials in a row of the same condition.

To determine how familiar infants were with the selected words, parents were asked on the day of testing to estimate how often their infant heard each word tested in the experiment from '1' (rarely: never/once per week), '2' (one time per day) to '3' (several times per day). The mean response was 1.67 ($SD = 0.33$) (data for three infants not available). Poltrock and Nazzi (2015) reported a mean response of 1.85 ($SD = 0.31$) for fullterm infants.

RESULTS

Mean orientation times (OTs) to the lists containing the familiar words versus the pseudowords were calculated for the preterm group. For comparison purposes, OTs from the same lists were obtained for the group of fullterm infants (Poltrock & Nazzi, 2015). A two-way repeated measures analysis of variance (ANOVA) with the between-subject factor of group (preterm versus fullterm) and the within-subject factor of familiarity (familiar words versus pseudowords) was conducted. The effect of familiarity was significant, $F_{(1,42)} = 21.1$, $p < .001$, $\eta_p^2 = .334$, indicating that infants preferred familiar ($M = 8.17$ s, $SD = 2.93$) over pseudowords ($M = 6.59$ s, $SD = 2.16$). Moreover, 34 of 44 infants oriented longer to familiar words than to pseudowords (binomial test, $p = .0002$). The effect of group ($F_{(1,42)} = 1.65$, $p = .206$, $\eta_p^2 = .038$) and the familiarity x group interaction failed to reach significance ($F_{(1,42)} = .368$, $p = .547$, $\eta_p^2 = .009$). Despite the lack of interaction, we conducted paired t-tests in both groups to confirm the

familiarity effect, in the preterm group, $t(1,19) = 2.45$, $p = .02$, Cohen's $d = .548$, and in the fullterm group, $t(1,23) = 4.24$, $p < .001$, Cohen's $d = .865$ (see Figure 3.1). Moreover, this pattern of preference was found in 15 of the 20 preterm infants ($p = .021$, binomial test) and 18 of the 24 fullterm infants ($p = .011$, binomial test).

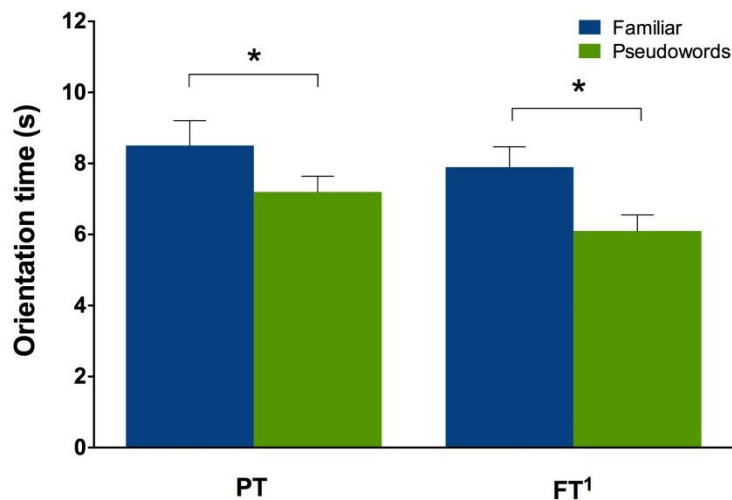


Figure 3.1. Mean orientation times (and standard errors) to familiar versus pseudowords. ¹Fullterm data from Poltrock and Nazzi (2015). * = $p < .05$.

Although the group of preterm participants only included a very small number of very preterm infants, we explored the possibility that familiarity effect was associated to degree of prematurity. *Pearson* (unilateral) correlations were run between the familiarity effect (attesting preference for familiar words) and infants' gestational ages, birth weights, and duration of hospital stay. All correlations between difference scores (orientation times to target minus control words) and infants' characteristics failed to reach significance (gestational age: $r = -0.22$; $p = .83$; birth weight: $r = -0.13$; $p = .71$; stay in hospital: $r = 0.08$; $p = .63$).

DISCUSSION

The main goal of the present study was to evaluate early recognition of familiar word forms in preterm infants at the same postnatal age as reported for their fullterm peers (Poltrock & Nazzi, 2015). The results show that French-learning preterm infants at 11 months of postnatal age, the majority of them being moderate and late preterm (17 out of 20), prefer a list of familiar word-forms over a list of pseudowords.

Furthermore, our results revealed no effect of group between preterm and fullterm infants. These findings establish, for the first time, successful word-form recognition of familiar words in 11-month-old preterm infants at the same postnatal age as their fullterm counterparts.

Our results converge with previous crosslinguistic studies on 11-month-old fullterm infants demonstrating preference for familiar words over unfamiliar words or pseudowords using HPP (French: Hallé & de Boysson-Bardies, 1994; English: Vihman et al., 2004; Dutch: Swingley, 2005). Why do our preterm infants recognize familiar word-forms but show later delays in lexical comprehension in standardized tests of language assessment (e.g. Caravale et al., 2005; Saavalainen et al., 2006)? First, our results demonstrate a general recognition of familiar word-forms and not actual comprehension. Previous research on word recognition using the LWL paradigm have found that very preterm children who have lower vocabulary outcomes at 36 months have similar accuracy rates but slower processing speed at 18 months maturational age (Marchman et al., 2016). It is possible that processing speed taps onto efficiency beyond a global recognition ability in typically developing infants (Fernald et al., 2006) and in infants at risk for later language deficits (Fernald & Marchman, 2012; Marchman et al., 2015, Ramon-Casas, et al., 2013). Our HPP paradigm, however, does not allow to evaluate processing speed, only overall recognition performance. A second likely explanation is related to the limited number of words used in our experiment, and their very high frequency in infant directed speech. Follow-up studies could explore this possibility by including different degrees of word frequencies in the infant's input presented in different lists in addition to a list of pseudowords. This might show that preterm infants differ from fullterms when presented with words with lower frequency levels. A third possibility is that moderate/late preterm infants (the majority of our sample) tend to have a more mature organism and fewer medical complications than extremely/very preterm allowing them to better benefit from early linguistic exposure. Thus, by the end of the first year, moderate and late preterm infants may be less delayed in certain developmental domains, an issue we will further discuss below. Including a larger number of very preterm infants in our sample (only 3 out of 20 so far) could test this hypothesis.

Our findings are in contrast with other preterm studies, on categorization in the second half of the first year (Perszyk et al., 2016) and on word recognition during the

second year (Loi et al., 2017), showing that preterm infants' word related abilities are more similar to those of their fullterm peers matched on gestational age. It is important to be cautious about direct comparisons since these tasks require different speech/cognitive processes and thus, may not be equally affected by prematurity. Another possible explanation for such differences is the criteria of inclusion: while in our study the participants were mainly moderate/late preterm infants, Perszyk et al. (2016) and Loi et al. (2017) included only very preterm infants. These findings are consistent with other studies on language assessment reporting that children born moderate to late preterm tend to have higher scores than those born extremely/very preterm at two years maturational age (Gayraud & Kern, 2007; Sansavini et al., 2006 Putnick et al., 2017).

The present study has some obvious limitations. We mainly included moderate/late preterm infants, and it is possible that word-form recognition abilities differ depending on degree of prematurity. We acknowledge that using a list of highly familiar words may lower the complexity of word recognition, which involves discovering word-form structure, its conceptual unit and learning this arbitrary relationship (Saussure, 1915; Waxman, 2003), and thus overestimate infants' measured abilities. Moreover, moderate and late preterm children usually do not go through the same medical experience as extremely and very preterm infants since they tend to have fewer health complications and shorter medical stays. The fact that they spend less time in a NICU environment might also have potential advantages for these children (in terms of having earlier access to rich social and linguistic interactions). Nevertheless, we believe that this first assessment of recognition of familiar word-forms offers some preliminary insight into the effect of prematurity in early word-form recognition.

Conclusions

Prematurity constitutes an important factor for later lexical development. We have demonstrated that preterm infants (mainly moderate and late preterms) recognize familiar word-forms at 11 months of postnatal age, similarly to their fullterm peers. Given the prevalence of the moderate/late preterm population and recent research pointing at later neurodevelopmental and academic deficits (de Jong et al., 2012; McGowan et al., 2011), the successful recognition observed in the present study may serve as a basis for future work evaluating word recognition abilities in the whole range of preterm infants and toddlers, either only auditorily or in audiovisual settings.

2. Experiment 8. The appropriateness of the use of postnatal age or maturational age in the assessment of expressive vocabulary: word production at 24 months

In the second year, particularly between 18-24 months, there is an increase in the speed of acquiring vocabulary, often called vocabulary spurt or lexical explosion (Bloom, 1976). Although the origin of this rapid increase is still a matter of debate, one of the possible explanations proposed is that it corresponds to a period when infants develop better conceptualization of objects and categorization abilities (Gopnik & Meltzoff, 1987; Nazzi & Bertoncini, 2003; for a detailed discussion on this issue, see Mayor & Plunkett, 2010). Furthermore, speech is undoubtedly a motor act. Indeed, it has also been argued that sound production abilities are related to increases in articulatory control but research in this domain is still limited due to the methodological difficulties in measuring articulatory movements in very young infants (Green, Moore, Higashikawa, & Steeve, 2000). On the other hand, research in vocabulary development has provided an important amount of data revealing that the size of the productive lexicon increases from around 50 words at 12 months to around 300 at 24 months (for crosslinguistic comparisons see, Wordbank: Frank, Braginsky, Yurovsky, & Marchman, 2016). However, it is important to highlight that there is great individual variation in vocabulary production in the 16-30-month range, even in typical developing children (Bates, Dale & Thal, 1995; Foster-Cohen et al., 2007).

Regarding children born prematurely, numerous studies during the second year of life report lower scores in productive vocabulary measures in this population compared to fullterm children, even when correcting for prematurity by using maturational age for comparison. Additionally, decreasing gestational age, specifically extremely and very preterm birth, has been associated to lower vocabulary scores (Gayraud & Kern, 2007). The following review of the literature is based on some representative studies that have used parent-reported questionnaires (e.g. MacArthur-Bates Communicative Development Inventory, or normed adaptations of this test in different languages). Despite the fact that most of this literature has reported differences between healthy preterm and fullterm infants, there are conflicting reports which have found slight or no differences. We will compare production scores across studies including different degrees of prematurity to serve as a background for our present experiment. Our general aim is to compare the appropriateness of assessing

expressive vocabulary (as reported by parents) in preterm infants at postnatal or maturational ages.

To date, the studies that have found differences between preterm and fullterm infants in their expressive language skills outnumber those reporting no differences. For example, at 18 months of maturational age, English-learning toddlers born between 30-36.5 GWs have lower productive vocabulary than their fullterm peers (64 vs. 105; Magill-Evans, Harrison, & Burke, 1999). At 24 months maturational age, Foster-Cohen and colleagues (2007) found a relationship between decreasing gestational age and lower productive scores (mean by group: EPTs = 181, VPTs = 250, FTs = 261). However, the authors note the important individual variability in all groups (see Figure 3.2., from Foster-Cohen et al., 2007).



Figure 3.2. Relationship between gestational age at birth and children's total vocabulary production (from Foster-Cohen et al., 2007).

In another study conducted in Estonian-learning children between 16 and 25 months, preterm children (mean GWs = 30, range: 24-35 GWs) were matched on maturational age and gender to fullterm children. The preterm group had smaller word production scores than the fullterm group but noteworthy, both displayed a similar pattern of vocabulary growth (see Figure 3.3.; from Schults, Tulviste, & Haan, 2013), indicating that the lag persists until the second year despite exhibiting the same developmental pattern.



Figure 3.3. Vocabulary size in fullterm and preterm infants at different ages (from Schults et al., 2013).

In French, one large study including over 300 preterm participants at 24 months of maturational age and 150 fullterm control participants revealed three main findings. The first finding was that extremely preterm born children showed lower productive scores than very preterm, moderate preterm and fullterm children. The second finding was that very preterm children also differed from fullterm children and, the third finding was that no differences were found between the moderate preterm and fullterm groups (Gayraud & Kern, 2007). A more recent study on very preterm children at 24 months of maturational age also reported differences in word production with respect to the fullterm population: 48% of these children were below percentile 10th and 63% below percentile 25th (Charollais, et al., 2014).

In contrast, other studies including extremely-to-late preterm children have found no differences in word production compared fullterm children. For instance, a recent study in Galician-learning children observed no differences between preterm born children and their fullterm peers at 22 and 30 months of maturational age (Pérez-Pereira, Fernández, Gómez-Taibo, & Resches, 2014). Since the study included extremely-to-late preterm born children, the authors grouped the participants into four groups (≤ 31 GWs, 32-33 GWs, 34-36 GWs, and ≥ 37 GWs) in order to compare their productive scores. No differences were found between the four groups, neither at 22 months nor at 30 months, indicating that no significant delays in word production were observed in preterm children, regardless of the gestational age at birth. In another

study including only Italian-learning very preterm children, their productive vocabulary at 24 months of maturational age tended to be below fullterms' scores but this difference was not statistically significant (mean VPTs = 44.97, FTs = 57.95), although perhaps the fact that the fullterm group was much smaller than the preterm group (VPTs = 104, FTs = 20) could explain why the difference did not reach significance (Sansavini et al., 2011). Despite the absence of significant differences, the authors point out that the risk of lexical development among preterm children was higher, as 20% of the preterm participants had scores below the 10th percentile. Likewise, at 30 months of maturational age, Italian-learning very preterm children did not differ from fullterm children in productive vocabulary (445.5 vs. 446), but a higher percentage of preterm children fell in the <5th percentile compared to fullterms (13.7% vs. 4.5%; Sansavini et al., 2006).

Similarly, the size of the productive lexicon in Finnish-learning preterm children (mean 28 GWs) at 24 months of maturational age did not differ from fullterm children, with similar trajectories in the main lexical categories (Stolt et al., 2007). The authors suggest that using maturational age may overestimate their lexical abilities. The issue of whether maturational or postnatal age might be more relevant for the assessment of linguistic abilities has been further addressed by Cattani and colleagues (2010). In a longitudinal study from 12 to 24 months, preterm children' word production scores on a standardized test (mean GWs = 31.8) were compared to normative scores according to their postnatal age and to the scores of a group of fullterm children matched on maturational age. The results showed that on the basis of postnatal age, preterm children lag behind fullterm children at 21 and 24 months. Notably, preterm children produced 50% fewer words than fullterms at the same postnatal age. The authors also compared their scores at postnatal and maturational ages to the percentile values of the normative sample. At 24 months of postnatal age, word production scores were at the 28th percentile whereas according to their maturational age, the scores were at the 47th percentile. However, it is important to underline that the study included a very small number of participants (N=12). Thus, these results seem to indicate that preterm children present a delay at 24 months of postnatal age that is reduced almost to half when correcting for prematurity.

In sum, research on word production during the second year of life has provided contrasting results regarding preterm children' vocabulary development.

Although not all studies find differences in vocabulary size, an important percentage of preterm children have productive scores in the lower percentiles (below 10-25th). In the present study, we will try to contribute to this research by examining the appropriateness of using postnatal and maturational age at the age of two years, since there is a standard practice of correcting for prematurity until 24 months in developmental assessment (Wilson & Cradock, 2004).

Two issues have generated discussion in clinical practice due to possible subsequent eligibility for intervention programs. The first issue concerns the appropriateness of the use of postnatal and maturational age in different domains (e.g. motor, cognitive skills). For instance, Wilson & Cradock (2004) review some studies on motor skills in which, in the first year of life, very preterm infants assessed at their maturational age performed below their fullterm peers on motor skills but not on mental skills (Ross, 1985). Furthermore, other studies found that assessing motor skills at the maturational age is necessary until 18 months to compensate for differences between preterm and fullterm infants (Palisano, 1986).

The second issue concerns the appropriateness of correcting for prematurity in infants born extremely/very preterm with respect to those born moderate/late preterm. It is possible that differences between fullterm and moderate/late preterm infants cease to exist earlier than in extremely/very preterm infants. Some studies comparing the effect of assessment at postnatal and maturational age have revealed contrasting results. For example, Barrera, Rosenbaum, and Cunningham (1987) found that extremely and very preterm infants performed below 16-month-old fullterms at the same maturational age in cognitive, language, and motor development (BSID: Bayley, 1969) whereas moderate/late preterm showed no differences with respect to fullterm infants at 12 months postnatal age. If this finding were confirmed in future studies including all degrees of prematurity and larger cohorts, it would suggest that correcting for prematurity should cease earlier in moderate/late preterm infants than in extremely/very preterm infants but, importantly, that this could depend on the domain assessed.

Goal of the experiment

In light of the general picture described above, the aim of the present study was twofold: to investigate the appropriateness of using postnatal and maturational age in assessing productive vocabulary and to explore whether assessment at both ages is equally relevant for all degrees of prematurity. In order to do so, we will compare preterms' productive vocabulary scores around the age of 2 years to the normative percentiles at their postnatal and maturational ages, as done by Cattani et al. (2010) but increasing the number of participants. We use the French adaptation of the MacArthur Communicative Development Inventory (Words and Sentences, Kern, 2003) to allow for comparison with previous studies described above.

To the extent that language production requires articulatory-motor processes, we hypothesize that preterm infants will perform below their fullterm peers when matched on postnatal age. However, after adjustment, we expect them, on the basis of the literature reviewed above, to perform as the fullterm population, hence, to have a mean percentile close to the 50th of the normed mean. Furthermore, as reported in previous studies, we expect a higher proportion of preterm infants at risk for language delays than in the fullterm population (Charollais et al., 2014, Sansavini et al., 2006). Lastly, if very preterm infants are more affected by the development of motor skills, we would expect them to show a greater difference between their scores at postnatal and maturational ages than moderate and late preterm infants (an issue that will require further testing due to the small sample size of the very preterm subgroup at this point).

METHODS

Participants

Twenty-seven healthy preterm infants (M postnatal age = 25 months and 6 days, SD = 0.84; M maturational age = 23 months and 14 days, SD = 0.85; 12 females) were tested. In the group of preterm infants, seven were born at < 32 GWs (M = 29.0; SD = 2.4) and twenty were born ≥ 32 GWs (M = 34.7; SD = 1.3; see Table 3.4. for additional neonatal characteristics). The inclusion criteria were being monolingual (more than 80% of input in French), with no reported hearing or serious health problem (brain injury, long retinopathy, or surgical intervention). Language background and health was assessed through parental interview and the child's health booklet.

Table 3.4. Neonatal characteristics of the participants.

| | Mean (SD) | Range |
|-------------------------------|-------------|----------|
| Neonatal History | | |
| Gestational age (wk) | 33.2 (3.0) | 25-36 |
| EPT (<28 wks, (<i>n</i> = 2) | | |
| VPT (28<32) (<i>n</i> = 5) | | |
| MPT (32<34) (<i>n</i> = 5) | | |
| LPT (34<37) (<i>n</i> = 15) | | |
| Birth weight (g) * | 2.089 (585) | 740-2900 |

*Information for two VPT infants is not available.

Materials and procedure

The data for this study were gathered using the French adaptation of the MacArthur-Bates Communicative Development Inventory: *'Mots et Phrases'* Words and Sentences, the version for children aged 16-30 months (Kern, 2003). The first part consists of a list of 690 words grouped into 22 different semantic categories (animals, clothes, food, etc.). These items belong to 4 different grammatical categories (nouns, predicates, closed-class items and 'others' which include animal sounds, games and routines). The second part evaluates morphological and syntactic development. It includes 25 items divided into 3 sections: the first one addresses the use of morphemes (articles, pronouns, prepositions, subject-verb agreement, etc.); the second one addresses the use of different tenses (infinitive, present, past, etc.), and the third one addresses the maximum length of utterance produced by the child. Only the first section was taken into consideration in this study: word production.

Parents were asked to check the words that their child produced. An information sheet gathered information about the child developmental history and languages heard.

RESULTS

To respond to the first research question, lexical production size was analyzed as a function of postnatal age and maturational age. First, each infant's total vocabulary score was compared to the percentile values of the normative data for French, taking gender into account. We obtained two percentile scores: one for the

child postnatal age and another one for the child maturational age. First, we present two histograms for the number of children in each percentile according to their postnatal or maturational age (Figures 3.4 and 3.5). The mean percentage for postnatal age was 38.5 percentile ($SD = 25.8$) and for maturational age, it was 51.5 percentile ($SD = 32.8$). Then, we conducted chi-square analyses to determine whether the distribution of the infants according to their postnatal and maturational age was different from the normative data. To perform the chi-square analyses, we divided the distribution into four categories (see Table 3.5). This choice was motivated by previous studies highlighting the high percentage of preterm children below the 10th percentile (Charollais, Stumpf, De Quelen, Rondeau, Pasquet, & Marret, 2014; Sansavini, Guarini, Alessandroni, Faldella et al., 2006). For postnatal age, this difference was significant ($\chi^2 = 12.63$, $p = .006$), but for maturational age, it did not reach significance ($\chi^2 = 5.41$, $p = .14$).

Table 3.5. Number of infants in each category for the comparison of distributions between the normative data versus the postnatal and maturational ages ($N=27$).

| | Percentile | | | |
|--------------|------------|-------|-------|--------|
| | 0-10 | 11-50 | 51-90 | 91-100 |
| Normative | 2.7 | 10.8 | 10.8 | 2.7 |
| Postnatal | 7 | 14 | 6 | 0 |
| Maturational | 6 | 7 | 11 | 3 |

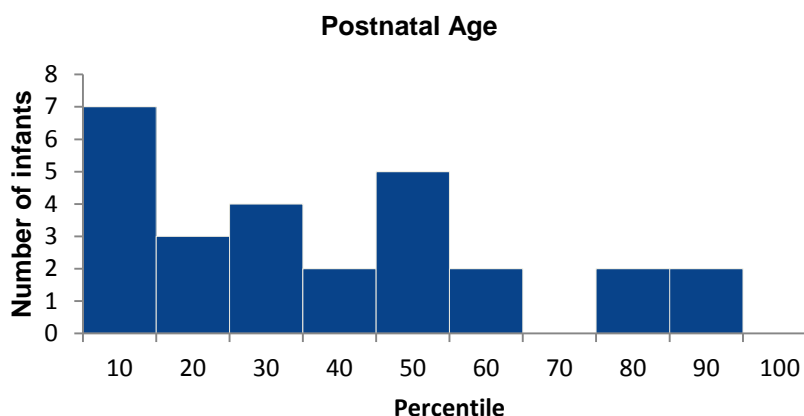


Figure 3.4. Histogram showing the distribution of scores on the normed CDI percentiles according to postnatal age.

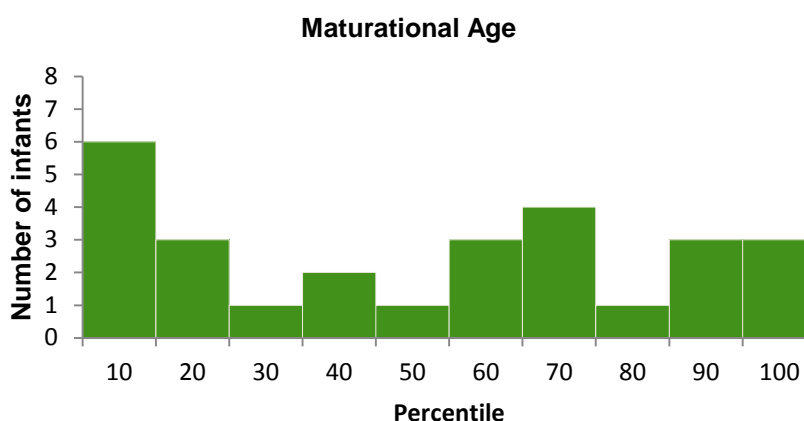


Figure 3.5 Histogram showing the distribution of scores on the normed CDI percentiles according to maturational age.

To compare the median percentile of preterm infants at each age to the median of the fullterm population (50th percentile), a Wilcoxon signed rank test was performed. The scores of preterm infants at postnatal age were significantly below the 50th percentile, $p = .037$. However, the difference between the median at the maturational age and the 50th percentile was not significant, $p = .80$.

When infants were assessed according to their postnatal age, we observe an asymmetric distribution (skewed right). Of the 27 children, 78% fell below the 50th percentile, and, 26% below the 10th percentile at postnatal age. Of the 7 children below the 10th percentile, 5 (out of 20) were moderate/late preterm children (thus

constituting 25% of this subgroup), and 2 (out of 7) were extremely/very preterm children (thus constituting 28% of that other subgroup). When matched on maturational age, the distribution was more symmetrical, as 48% performed below the 50th percentile. However, the number of children in the 10th percentile remained similar to that of postnatal age, representing 22% of the participants. Of the 6 children below the 10th percentile, 4 (out of 20) were moderate and late preterm born children (thus constituting 20% of this subgroup), and 2 (2 out of 7) were very preterm born children (thus constituting 30% of that other subgroup).

To respond to our second question, that is, whether adjustment to maturational age is appropriate for all degrees of prematurity, analysis were performed by subgroup. A paired-sample t-test was conducted to compare the percentile scores at the postnatal versus maturational ages. Due to the small sample size in the extremely/very preterm group, this analysis needs to be considered as very preliminary, and is only provided for information to explore the trends of the scores. In the extremely/very preterm subgroup, there was a significant difference in the scores for postnatal age ($M = 41.4$, $SD = 26.1$) and maturational age ($M = 61.4$, $SD = 37.6$); $t(6) = 3.46$, $p = .013$.

In the moderate/late preterm subgroup, the difference between the scores for postnatal age ($M = 37.5$, $SD = 26.3$) and maturational age ($M = 48.0$, $SD = 31.2$) was significant; $t(19) = 4.70$, $p < .001$. These results indicate that assessment at postnatal versus maturational age affects how moderate and late preterm infants fall within the normalized distribution. The Wilcoxon signed rank test indicated that the median percentile of the subgroup of moderate/late preterm infants at postnatal age compared to the median of 50 (percentile) in the fullterm population was marginally significant, $p = .069$. The comparison between median percentile at maturational age and the median of 50 of the fullterm population was not significant, $p = .746$.

DISCUSSION

The first aim of the present experiment was to evaluate the effect of using postnatal versus maturational age on word production assessment in preterm children around the age of 24 months. The comparison reveals that when assessed at postnatal age, the distribution of the scores of the preterm children is right skewed, with 78% of the participants performing below the 50th percentile. When assessed according to their maturational age, the distribution observed is more symmetrical, with

48% of the participants performing below the 50th percentile. The analyses also revealed that the median percentile of the preterm infants was below the 50th percentile of the fullterm population at postnatal age, but did not differ from it at maturational age. The results obtained in this sample suggest that maturational age scores are more appropriate for the assessment of word production than postnatal age, given that they reveal a more balanced distribution and a median similar to the normative data. Moreover, a high percentage of infants performed below the 10th percentile. Importantly, this percentage remained stable regardless of whether the scores were compared to the normative postnatal or maturational age percentiles (26% and 22%, respectively). This suggests that assessment at postnatal age might constitute an index for early identification of preterm infants at risk for lexical development at 24 months.

The second aim of the experiment was to explore the appropriateness of assessment at postnatal and maturational age in the subgroup of moderate and late preterm infants. The difference between the scores at postnatal and maturational ages was significant. Though results failed to find a statistically significant difference between the median scores at postnatal or maturational age compared and the normed 50th percentile, the difference between postnatal age and the 50th percentile was marginally significant. We will discuss each of these points in turn.

Regarding the distribution of our data and the comparison of the median scores to the fullterm population, our results are similar to Cattani et al. (2010), who reported that at 24 months postnatal age, preterm children were below the 50th percentile but when correcting for prematurity, the mean scores almost reached the 50th percentile. Likewise, our study included children from different degrees of prematurity from extremely-to-late preterm born children. Hence, it is possible that the similar results are related to the common criteria of inclusion and age of assessment. Similarly, in a study including over a hundred healthy preterm participants ranging from extremely-to-late preterm, no differences were found between the different preterm subgroups and the fullterm group in word production at 22 and 30 months maturational age (Pérez-Pereira et al., 2014). Since in Pérez-Pereira et al.' (2014) study children were only assessed at maturational age, it is possible that the group of moderate and late preterm born children had “caught-up” earlier in development (Barrera et al., 1987). This highlights the importance of further assessing the

appropriateness of correcting for prematurity in all degrees of preterm birth in larger sample sizes.

In addition, our results indicate that an important percentage of preterm children are at risk for lexical development, in accordance with other studies reporting a large percentage of very preterm children in the lowest percentiles. For instance, two studies in very preterm children at 24 months of maturational age have reported 20% and 48% of the children below the 10th percentile (Charollais et al., 2014; Sansavini et al., 2006;). In the present study, regardless of whether infants were matched to postnatal or maturational age, the percentage of children performing below the 10th percentile was around 25%. In contrast with the previous studies, the majority of the children in the present study were moderate and late preterm, which indicates that an important percentage of this subgroup might also be at risk for lexical development. Therefore, using postnatal age for assessment might be especially useful for an earlier detection of possible lexical deficits, and to devise possible intervention programs when necessary. Further studies are needed to better understand such differences including possible confounding factors, such as the role of medical history, early environment (e.g. duration of stay in the incubator, presence of the parents), gender or parental socioeconomic status.

With respect to the moderate/late preterm subgroup, there was a non-significant trend to perform below the 50th percentile when assessed at postnatal age. If this trend is confirmed, it would suggest that evaluation of moderate/late preterm infants is also affected by the choice of postnatal age for assessment of vocabulary production. Such findings in this particular domain would be in contrast with previous neurodevelopmental studies showing that moderate/late preterms show no differences with respect to fullterm infants at 12 months postnatal age, which had suggested that correcting for prematurity after the first year would be no longer necessary (Barrera et al., 1987). In language assessment in particular, it would raise new questions regarding assessment of different abilities that might require different neural mechanisms. Infants could show similar abilities at the same postnatal age in some perceptual domains while they would need additional time and maturation to acquire motor skills necessary for speech articulation. For example, Gonzalez-Gomez and Nazzi (2012a) observed that while very preterm infants at 10 months of postnatal age showed the same auditory preference for labial-coronal patterns as fullterm 10-month-olds, preterm infants had

poorer babbling abilities than fullterms matched at the same maturational age of 7 months. Future research comparing perceptual and production scores at postnatal and maturational age will help to better understand the relative contribution of postnatal experience and maturational constraints in different domains.

The present study has some limitations that include the small size of the subgroups, especially the very preterm sample. Data from a larger number of participants would provide more precise and convincing answers regarding the possible effects of the degree of prematurity. Another limitation of the study is the lack of control fullterm groups to perform other types of statistical analyses. Previous studies comparing groups of fullterm and preterm children at the same maturational age usually report differences, with preterm infants scoring below their fullterm peers (Foster-Cohen et al., 2007; Magill-Evans et al., 1999; Schults et al., 2013). However, this difference was not consistently found either in very preterm children or in moderate and late preterm children (Pérez-Pereira et al., 2014; Sansavini et al., 2011; Stolt et al., 2007). The group of participants of the present study included a larger number of moderate and late preterm infants who have been found to have scores more similar to fullterm children (Gayraud & Kern, 2007). Yet, there were 22% of the children below the 10th percentile.

In conclusion, the present experiment showed that preterm infants, even if they were predominantly born moderate and late preterm, have smaller vocabularies than fullterms of the same postnatal age, but as a group have similar levels as their fullterm, maturational age peers. However, more preterm infants were below the 10th percentile than expected based on fullterm norms, based on either postnatal or maturational age, suggesting that assessment at postnatal age might constitute an index for an earlier identification of preterm infants at risk for linguistic delays.

3. Chapter Discussion

This dissertation began by investigating word segmentation abilities in preterm infants, an ability that has been related to receptive and expressive vocabulary at the age of two years (Junge et al., 2012; Junge & Cutler, 2014; Kooijman et al., 2013; Newman et al., 2006). Chapter 1 found basic segmentation abilities at the same postnatal age as their fullterm peers; however, the literature reports later vocabulary delays in preterm children, even when correcting for prematurity by using maturational age (Caravale et al., 2005; Foster-Cohen et al., 2007; Gayraud & Kern, 2007; Saavalainen et al., 2006; Saavalainen et al., 2006; Sansavini et al., 2011). For this reason, the goal of the present chapter was to broaden our knowledge of word related abilities in this population by addressing early stages of word recognition and word production at a period of vocabulary expansion.

This chapter began by testing preterm infants' abilities to recognize a list of familiar word-forms at 11 months of postnatal age, the age at which it emerges in for fullterm infants (Hallé & de Boysson-Bardies, 1994; Poltrock & Nazzi, 2015). We found that preterm infants preferred to listen to familiar words over pseudowords. However, our results should be mainly interpreted for moderate and late preterm infants, who constituted the majority of the participants. This finding indicates that (mostly moderate/late) preterms show an effect of familiarity for word forms that are commonly heard in infants' everyday life. We proposed that this ability found in preterm infants at the same postnatal age as their fullterm peers could be explained by recognition of familiar word sounds, which does not involve actual comprehension of their meaning as in the LWL paradigm. Previous research from the age of 18 months postnatal age has found that preterm word comprehension skills are more similar to that of their fullterm peers at the same maturational age than postnatal age (Loi et al., 2017). It is plausible that the difference between our results and Loi et al' (2017) results stems from different processes involved in word recognition/word learning. The recognition of familiar word-forms at the auditory level might require a less detailed lexical representation, while word recognition demonstrates understanding of a word by mapping its phonological characteristics to the concept it represents (Waxman, 2003). Joint attention and gaze following play an important role in the process of word learning (Carpenter et al., 1998; Morales et al., 1998), a process that

necessarily requires the use of visual and auditory cues. Hence, it is possible that the delay observed in word recognition during the second year reflects some constraints related to the conjoined use of visual and auditory cues that might tap onto other mechanisms affected to a greater extent by prematurity.

The second section was devoted to the appropriateness of assessment of word production at postnatal and maturational ages. Our results showed that the distribution of the preterm infants was more similar to the fullterm population at the same maturational age. They were also closer to the 50th percentile of the fullterm population when assessed at the maturational age than at the postnatal age. These findings indicating that maturational age replaces the level of preterms' word production abilities within the normative population was also found in the subgroup of moderate and late preterm infants.

Although the results of familiar word-form recognition and word production might seem contradictory, each domain may require different cognitive mechanisms, representing different challenges to the brain. Neuroimaging studies investigating the link between sensorimotor circuits and perception in language have demonstrated that speech sounds elicit activation in motor areas (for a review, see Pulvermüller & Fadiga, 2010). However, studies in language acquisition have demonstrated that recognizing words in the speech stream is also possible in the absence of strong articulatory abilities (Saffran, Aslin, & Newport, 1996) and that this ability is also present in non-humans (Hauser, Newport, & Aslin, 2001). The recognition of familiar word-forms at the auditory level may require a less detailed lexical representation and less motor activation than word production. Some studies on preterm infants have reported that motor skills are delayed compared to other cognitive skills (Ross, 1985), but many questions remain to be explored regarding the effect of prematurity on the development of different domains. Hence, for premature infants, the delay in the acquisition of motor skills could affect the feedback between the motor system and linguistic perception mechanisms leading to a potential delay in word production abilities. Future work would need to test this prediction of the involvement of neurobiological factors and the specific role of the motor systems in the emergence of speech perception and production abilities in preterm infants. Further, such studies could extend into early childhood by testing whether and how motor abilities influence

the process of learning to write and to read and possible cascading effects as language abilities become more complex.

In summary, at the level of speech sound perception/processing, preterm infants demonstrate recognition of a list of familiar word-forms at the same postnatal age of 11 months as previously reported for fullterm infants. In contrast, when assessing word production abilities, maturational age seems to be more appropriate, even for moderate and late preterm infants, for comparison with the fullterm population. This suggests that prematurity might differently affect perception and production abilities (leaving open the issue for comprehension abilities). We see this proposal as an opportunity to further evaluate the possible implications of the development of the motor system in both domains in an effort to understand the intricacies of the role of experience and maturation on early (preterm) language acquisition.

GENERAL DISCUSSION

Preterm born infants experience a difficult beginning in life since they have to develop under different circumstances than mature fullterm born infants. The prevalence of preterm births, defined as before 37 weeks of gestation, is steadily increasing worldwide, representing about one in ten births (Blencowe et al., 2012). In the last two decades, studies using standardized methods of language assessment have revealed that preterm born infants are at risk for developing language delays and experience academic difficulties throughout school years (Barre et al., 2011). Thanks to our increasing knowledge on early perception abilities in typically developing infants, more researchers have recently focused on understanding language development in preterm born infants to test the validity of different hypothesis related to the effect of prematurity. This dissertation contributes to this line of work.

The most common hypothesis is related to the main effect of prematurity on the *timing* of acquisition of a given milestone. Different studies seek to investigate the contribution of extrauterine experience and neural maturation on achieving the performance level of fullterm infants. If this achievement is more determined by maturation, this is usually interpreted as a temporary delay in development. On the other hand, from an environmental point of view, if experience plays a more important role in the achievement of a given ability, it suggests that environmental factors, in this case, exposure to broadcast speech, may have a stronger influence than biological factors. Other hypotheses have put forward that early disruption of the intrauterine development together with early exposure to extrauterine environment, hence a disruption of the typical synchronicity, can lead to atypical development (Karmiloff-Smith, 1998).

Recent findings suggest that preterm infants' speech perception abilities during the first year cannot be categorically attributed to either postnatal or maturational status. According to these studies, preterm infants' performance depends on the type of experience (e.g. experience with prosody, experience with high frequency sounds) and the type of cue (e.g. segmental, suprasegmental, social, visual) that are more relevant for early acquisition in different linguistics subdomain. Given that the developmental picture of preterm infants is still emerging, the first goal of this doctoral research was to specify different speech perception abilities in the first two years of life in preterm infants, comparing these abilities to those of fullterm infants of the

same postnatal age. The second goal was to investigate whether degree of prematurity modulates linguistic performance across preterm infants.

In this chapter the main results of the previous chapters will be discussed, followed by a discussion on the possible effect of prematurity on different subdomains. Then, we will review the role of degree of prematurity in light of our findings, and issues related to biological factors and brain development. Lastly, the strengths and limitations of the present dissertation as well as future research directions will be described.

1. Summary of results

1.1. Infants born preterm segment syllabic units at 6 months postnatal age

In Chapter 1, the ability of extremely-to-late preterm infants to segment the syllabic unit was investigated. The first question that we aimed at answering was whether segmentation abilities could be found in this population. The choice of exploring this ability is motivated by evidence from the past twenty years showing that infants from different language backgrounds start segmenting speech, usually around 6-8 months (English: Jusczyk & Aslin, 1995; Jusczyk, et al., 1999; German: Höhle & Weissenborn, 2003; French: Goyet, et al. 2013; Nazzi, et al., 2014; Nishibayashi, et al., 2015; Spanish and Catalan: Bosch, et al., 2013) and from several studies that have found a link between segmentation abilities and later vocabulary outcomes (Junge et al., 2012; Junge & Cutler, 2014; Kooijman et al., 2013; Newman et al., 2006). Given that children born preterm (especially extremely/very preterm) are found to score below their fullterm peers around vocabulary spurt (2 years) in standardized tests, Experiments 1-5 were conducted to investigate the emergence of segmentation skills in this population with respect to fullterm infants.

Results of Experiment 1 showed successful segmentation of monosyllabic words (attested by a significant difference in orientation times between familiar words and control words after a familiarization phase) at 6 months of postnatal age, as previously found for fullterm 6-month-olds (Nishibayashi et al., 2015). Since no studies had investigated segmentation abilities in fullterm infants before the age of 6 months, Experiment 2 tested a group of 4-month-old fullterm infants to answer two questions, whether segmentation abilities could be found in younger fullterm infants and whether preterm infants' successful segmentation abilities (Exp. 1) could be explained by

postnatal experience with speech if younger fullterm infants failed to segment. The results showed that 4-month-old fullterm infants also segment monosyllabic words, bringing down the onset of such ability in fullterm French-learning infants. Based on these results, we argued that this early segmentation of the syllabic unit by French-learning infants further supports the early rhythmic segmentation hypothesis (Nazzi et al., 1998, 2000, 2006). This hypothesis states that infants may learn the rhythmic segmentation procedure appropriate to their native language by making use of the rhythmic unit of their native language. We also suggested the possibility that a syllable-based segmentation procedure might be bootstrapped by newborns' better processing of syllables over other linguistic units (Bertoncini et al., 1988).

In a follow-up experiment (Exp. 3), we found evidence showing that preterm 6-month-old infants segment the syllabic unit even when embedded in larger words, as previously found in fullterm infants of the same postnatal age (Nishibayashi et al., 2015). However, we observed that the direction of the effect between both populations was opposite: a novelty effect in preterm infants and a familiarity effect in fullterm infants. We posited that the different behavioral responses observed could signal different speech processing mechanisms between preterm and fullterm infants. As described in the General Introduction, previous studies using fMRI and EEG have revealed different activation patterns and ERP responses during linguistic processing in preterm infants and children relative to fullterms (Peterson et al., 2002; Therien et al., 2004). Behavioral experiments measuring looking behavior have also demonstrated that very preterm born toddlers show slower information processing in language measures than their fullterm peers, even at maturational age (Ortiz-Mantilla, Choudhury, Leever, & Benasich, 2008; Ramon-Casas et al., 2013, Marchman et al., 2016). Furthermore, processing speed and working memory deficits have been found to affect their academic achievement during childhood (Mulder, Pitchford, & Marlow, 2010). Thus, we suggested that the novelty effect found in preterm infants may reflect speech/information processing difficulties. Further experiments on early speech processing abilities using brain techniques should be conducted to test this differential processing hypothesis. Crucially though, the segmentation effects for monosyllabic words and embedded syllables found in preterm infants at 6 months postnatal age establish, for the first time, that basic segmentation procedures corresponding to the rhythmic unit of the native language are in place in preterm infants.

Moreover, the failure to find evidence of a consonant bias in recognition of segmented word forms as found for fullterms of the same postnatal age of 8 months (Nishibayashi & Nazzi, 2016) could also indicate cognitive limitations affecting preterm infants' segmentation skills (Exp. 4). This interpretation is also based on results from a group of 6-month-old fullterm infants showing a vowel bias in the same task (Nishibayashi & Nazzi, 2016). Due to recruiting constraints, our preliminary results can only provide partial evidence of infants' performance at this point. Thus, the lack of significant differences in orientation times between the two types of mispronunciations of the familiar word heard during familiarization has been interpreted as a possible early difficulties revealed by a more cognitively demanding task. Such early speech processing difficulties might, in turn, be detrimental for later lexical acquisition. Preterm toddlers have been found to have slower lexical speed processing than their fullterm peers, even at the same maturational age, in word recognition tasks (18 months: Ramon-Casas et al., 2013), a processing efficiency that has been related to later vocabulary levels (24-36 months: Marchman et al., 2016). Testing how preterm infants' segmentation abilities interact with later lexical development will shed new light onto the potential effects of prematurity on language acquisition.

1.2. Do prematurity and bilingualism influence early word segmentation abilities?

In Experiment 5 of Chapter 1, we aimed at exploring whether the combination of two factors, prematurity and bilingualism, affects early word segmentation abilities. Experiment 1, showing successful segmentation of monosyllabic words in 6-month-old preterm infants, served as a baseline for Experiment 5 in which we tested bilingual preterm and fullterm infants under the same experimental conditions. Our preliminary results show a trend in the same direction as the one observed for monolinguals, which if confirmed, will provide new data to recent evidence attesting segmentation abilities in bilingual infants at the same age as their monolingual peers (Bosch et al., 2013; Polka et al., 2017). Furthermore, these results would add to previous research on different subdomains revealing that bilingual and monolingual infants acquire language milestones at similar ages (Werker, 2012).

We considered that these somewhat surprising results could be explained by several factors. One is that bilingual infants, even if they have received less input in each of their languages than their monolingual peers (Byers-Heinlein & Fennell, 2013),

have had enough experience with French to start developing basic segmentation abilities, as supported by the results from Experiment 2 establishing that only 4 months of experience with French are sufficient to show successful segmentation in monolingual fullterms. Furthermore, although the bilingual infants included in the present experiment had a second language that could be syllable-based or not, they were all either balanced or French-dominant bilinguals, which might have provided them with enough French input at 6 months to observe basic segmentation abilities. Could that specific language dominance profile have been crucial to our findings?

In infancy, few studies have investigated on the possible effects/role of language dominance on the emergence of sensitivities to language-specific properties. These studies show contrasting results. For instance, Bijeljac-Babic et al. (2016) found that a trochaic bias was present in 6-month-old French-German bilinguals as in German monolinguals (Höhle et al., 2009) and that the size of the trochaic bias was not related to the amount of exposure to German. In another study, Abboub, Bijeljac-Babic, Serres, & Nazzi (2015) showed that 10-month-old bilingual infants exposed to French and another language with lexical stress discriminate iambic-trochaic word patterns regardless of their amount of exposure to the stress language (as low as 30%), an ability that has been found in monolinguals exposed to a language with lexical stress (Skoruppa et al., 2009). In contrast, another study found that the iambic-trochaic discrimination was only present in a group of bilinguals that had a language with lexical stress as dominant language, but not in balanced bilinguals (Bijeljac-Babic et al., 2012). Similarly, Sebastián-Gallés & Bosch (2002) found that 10-month-old Spanish-dominant Catalan bilingual infants present less sensitivity to phonotactic patterns of Catalan than their Catalan-dominant Spanish bilingual peers. Given the currently scarce data available and the differences in the results obtained, it is still premature to draw firm conclusions regarding the effects of language dominance on early language acquisition.

Given our present knowledge of early bilingual acquisition, it could be that the development of early language-specific segmentation abilities in bilingual infants is related to the amount of input in each language, which, in turn, would impact, among other factors, lexical acquisition. In previous research, bilingual children (between 1:10 to 2:3 years) have been found to score below monolingual infants in vocabulary measures in each of their languages. However, when considering their total vocabulary

in both languages, they perform similarly to monolinguals (Hoff et al., 2012). Moreover, amount of exposure in each language has been related to language proficiency in bilingual children (Gathercole & Thomas, 2009; Hoff et al., 2012; Scheele, Leseman, & Mayo, 2009). This potential effect of language dominance on segmentation abilities would need to be further tested on bilingual infants with different amount of exposure to their two languages and learning different pairs of languages (of same or different rhythms). This research topic has only recently begun to be explored (e.g. Polka et al., 2017) and would contribute to broaden our knowledge on how bilingual input may modulate the development of segmentation procedures. Whether non-French-dominant preterm and fullterm bilinguals would succeed at monosyllabic word segmentation remains a question.

1.3. Early impact of prematurity on audiovisual speech

In Chapter 2, using eye-tracking techniques, we measured preterm and fullterm infants scanning patterns of a talking face in the native (French) and a non-native (English) language. Preterm infants at 8 months postnatal age demonstrated different looking behavior than their fullterm peers matched on either postnatal or maturational age. Compared to fullterm infants who showed different scanning pattern of the face speaking in the two languages, preterm infants showed similar scanning patterns for both languages. In particular, they looked proportionally less to the eyes for the native language than 6- and 8-month-old fullterm infants. Our results only partially support previous evidence showing that infants allocate more attention to the mouth in the presence of unfamiliar speech during the second half of the year (Lewkowicz & Hansen-Tift, 2012; Pons et al., 2015). We suggested that these differences could be explained by the type of stimuli we used, such as child-directed speech (instead of infant-directed speech) and more eye and head movements in our stimuli.

Regarding the similar looking pattern for the two languages in preterm infants, we suggested that it could reflect processing speech difficulties associated to visual stimulation in an immature organism, to differential onset of visual and/or to auditory extrauterine exposure with respect to typical development, and early medical and social environments. Although such particular circumstances are more frequently encountered by extremely and very preterm infants, our results showed atypical looking patterns in a group consisting of a majority of moderate and late preterm infants (14 out of 22).

These findings suggest the need to further explore audiovisual speech perception not only in infants that are more vulnerable to more severe vision problems (i.e. retinopathy) but also those born later in gestational age. Future studies are encouraged to investigate the role of medical and environmental factors on audiovisual speech perception.

1.4. Word abilities

In Chapter 3, word-form recognition abilities were found in (mostly) moderate and late preterm infants at 11 months of postnatal age (Exp. 7). This finding is in accordance with previous studies on word form recognition in French-learning fullterm infants at the same age (Hallé & de Boysson-Bardies, 1994; Poltrock & Nazzi, 2015). They are also in line with studies on word recognition in very preterm toddlers reporting accuracy level above chance, although these studies were performed during the second year and corrected for prematurity (Loi et al., 2017; Marchman et al., 2016; Ramon-Casas et al., 2013). It could be that moderate and late preterm infants, having fewer medical complications than very preterm infants, develop better linguistic skills. Unfortunately, the present research could not include a balanced number of extremely/very preterm and moderate/late preterm infants to test for this possibility. Despite the lack of evidence in this domain, results from Chapter 1 demonstrate the presence of early segmentation abilities in all range of preterm infants at 6 months postnatal age. Given that we failed to find an effect of degree of prematurity at these younger ages (Exp. 1 and 3), it might be that recognition of familiar word-forms would also be found in very preterm infants if the impact of degree of prematurity decreases with increasing age. Alternatively, it is possible that the relationship between degree of prematurity and cognitive development is not linear, but relies on maturation. We will further discuss this issue in the sections “degree of prematurity” and “Biological factors and brain development” below.

With respect to word production scores at around 24 months of postnatal age (Exp. 8), we found that preterm infants have smaller vocabularies than fullterms of the same postnatal age, but as a group, have similar levels as their fullterm, maturational age peers. However, more preterm infants were below the 10th percentile than expected based on fullterm norms. These findings are in line with previous studies showing that 20 to 48% of very preterm children perform below the 10th percentile in productive

vocabulary measures at 24 months maturational age (Charollais et al., 2014; Sansavini et al., 2006). These results, together with our studies showing that some abilities are in place in preterm infants at the same postnatal age as in their fullterm peers (segmentation abilities, word-form recognition), raise the question about the use of maturational age when assessing cognitive skills in preterm infants for clinical purposes only. For clinical practice, assessing children at postnatal age might constitute an index for early identification of (preterm) infants at risk for delays in lexical development. For research practice, we suggest using both postnatal and maturational age to better specify the developmental course, as studies showing that efficiency in word recognition during the second year in very preterms is closer to their fullterm peers matched on maturational age than on postnatal age (Loi et al., 2017). It has also been found that moderate and late preterm infants assessed at 12 and 18 months of maturational age perform significantly below fullterm infants in neurodevelopmental tests (Bayley Scales of Infant Development II) when using their postnatal age. However, when correcting for prematurity level, they were similar to the fullterm population (Romeo et al., 2010). Use of both measures will allow to better estimate the developmental course of this population in the different subdomains, an issue we will discuss next.

2. Postnatal or maturational age: Does prematurity differentially affect different subdomains?

In the literature review on preterm infants' language development (General Introduction), it was suggested that prematurity may differentially affect different language subdomains. One specific proposal for the cause of this effect is that loss of exposition to filtered speech before birth would impact certain acquisitions more than others. This is difficult to test because the achievement of many abilities in language acquisition depends on the use that infants' make of both segmental and suprasegmental cues. One way we directly addressed this question was by investigating the emergence of the consonant-bias in French-learning preterm infants at 8 months postnatal age (Exp. 4), the age at which this bias had been previously been found in fullterm infants (Nishibayashi & Nazzi, 2016). Exposure to high frequency sounds being equal, we hypothesized that preterm infants might show a consonant-bias at the same postnatal age as fullterm infants. We failed to observe either a consonant bias as in

8-month-olds, or a vowel bias as in 6 month-old-olds (Nishibayashi & Nazzi, 2016). We therefore suggested that failure to observe a bias in these first preliminary results might have been due to the use of a segmentation task that increases complexity with respect to standard tasks (e.g. Exp. 1) and the difficulties that preterm infants might face with increasing cognitive demands (Exp. 3.; Bosch, 2011).

Despite failing to confirm this specific hypothesis about how prematurity affects language development, the rest of our research explored the extent to which different abilities are affected by preterm birth. These included the early segmentation of the simplest rhythmic unit (Chapter 1), the differential looking patterns in the presence of audiovisual native and non-native language (Chapter 2), the recognition of familiar word-forms at 11 months and word production at approximately 24 months (Chapter 3). We will discuss the implications of prematurity on each of these domains.

Regarding segmentation skills (Chapter 1), the use of the simplest CV structure together with the “special” status of the syllable at birth over other linguistic units might contribute to explain successful segmentation at such young ages in French-learning infants (4-month-old fullterms, 6-month-old postnatal age preterms). In order to evaluate the possible effect of lack of prosodic exposure in utero on segmentation skills, it might be more suitable to test this ability in stress-based languages, such as English, German or Dutch. So far, evidence on German-learning infants shows that, compared to fullterm infants at the same maturational age, preterm infants do not discriminate word stress patterns at 4 months (Herold et al., 2008), nor do they prefer the predominant stress pattern of their native language by 6 months (Höhle et al., 2009). According to these results, it could be hypothesized that subsequent segmentation skills might be delayed in this German-learning population. In contrast, the present results from Experiments 1, 3, and 5 demonstrate that basic segmentation abilities are in place in French, although they also reveal that these abilities might be constrained by cognitive demands. Moreover, more needs to be explained in French and future studies could test the use of other cues (in particular TPs) which are hypothesized to be crucial to segment multisyllabic words in that language. Thus, the effect of prematurity on language abilities may depend not only on the relative contribution of segmental and suprasegmental cues to the acquisition of different language subdomains, but also on the language-specific properties.

In the audiovisual domain, Chapter 2 explored looking behavior in a more “ecological” situation, as is the case of face-to-face interactions, by presenting infants with a face talking in the native or non-native language. This type of task measures infants’ attention allocation to the different facial features. The results of Experiment 6 showed different looking behavior between preterm and fullterm infants (at both postnatal and maturational ages) suggesting a complex effect of prematurity on audiovisual speech perception. We highlight three potential explanations for the different scanning patterns observed. One is the possible influence of premature visual exposure on the development of the visual system. A second explanation related to the effect of the differential onset of auditory and visual cues with respect to typical development by increasing competition between the developing sensory systems (Turkewitz and Kenny, 1982, 1985) and/or altering the brain development (Karmiloff-Smith, 1998). This differential timing could then have cascading effects in the integration of the audio and visual signals and the detection of their temporal correlation, as reflected, for instance, by preterms’ failure to match the temporal cues of fluent audiovisual speech during the first year (Pickens et al., 1994). A third possibility is that articulatory cues help infants to process speech, which could explain why fullterm infants looked less at the mouth relative to the eyes in the native than in the non-native language while preterm infants looked less to the eyes in the native language. Importantly, our results were not modulated by degree of prematurity although a larger number of moderate/late preterms (14/22) than extremely/very preterm infants (8/22) participated in the study. Thus, the results presented here indicate that attention allocation in the domain of audiovisual speech perception may be altered in preterm infants during the first year of life with respect to their fullterm peers. In other words, these results may point to a different developmental trajectory rather than a delay due to maturational constraints, since preterm infants’ looking behavior differed from both their postnatal and maturational age peers.

Chapter 3 targeted word-related perceptual and productive abilities. It revealed that preterm infants (mostly moderate and late preterm) preferred listening to familiar word-forms over pseudowords. We consider that this task is measuring an early “global” auditory recognition, which does not necessarily entail comprehension of the meaning of the words heard. Given that most of the infants were moderate and late preterm, we can only conclude that early familiar word-form recognition is not affected

at this degree of prematurity. However, our results on word production around the age of two years indicate that maturational age may be a more suitable measure for this aspect of expressive language, which elicited a discussion regarding the achievement of certain abilities at postnatal or maturational age depending on the linguistic domain considered. We suggested that because language production is mediated by motor skills which have been found to be delayed in preterms (Fallang et al., 2003), maturational age might be more appropriate than postnatal age. On the other hand, because speech perception recruits motor areas to a lesser extent than production skills, some perceptual abilities can be observed at the same postnatal age as fullterm infants (Exp. 1, 3, 7). Lastly, we cannot discard the possibility that other neurodevelopmental factors (e.g, visual processing, working memory) might contribute to delayed expressive language. Considering that in particular very preterm infants have been found to exhibit slower information processing speed (Marchman et al., 2016; Ramon-Casas et al. 2013; Rose et al., 1988), it is also possible they need additional time to encode information, slowing down subsequent expressive language development. Evidence from experiments investigating the contribution of each of these factors in perception and production will help understand what linguistic domains are more vulnerable to risk of later deficits.

3. The role of degree of prematurity

In addition to specifying the timing of achievement of certain abilities in preterm infants, the role of gestational age on their language performance was investigated. First of all, it should be noted that more research has focused on very preterm infants while knowledge on moderate and late preterm infants remains limited, although they constitute the largest proportion of infants born prematurely. When degree of prematurity was explored, it was usually done in terms of categorical groups based on gestational age, and rarely in terms of a linear variable. Hence, the analyses we conducted used prematurity both as a dichotomous variable (ANOVA with subgroups: extremely/very preterm vs. moderate/late preterms) and as a continuous variable (correlations) when possible, as a first approach to explore the role of gestational age.

In Chapter 1, we failed to find an effect of degree of prematurity on segmentation of monosyllabic words and embedded syllables in monolingual infants,

with a similar number of infants in each subgroup. In the bilingual preterm group, the trend towards a familiarity effect was there even if most of the infants were very preterm (12/17) but the results should be taken with great caution until the completion of the group. Moreover, since our results have small effects, it is possible that larger groups of infants would be necessary to find an effect of degree of prematurity. In Chapters 2 and 3, the results correspond to a larger extent to the abilities of moderate and late preterm infants, who were more numerous than very preterm infants. Nevertheless, even when considering gestational age as a continuous variable, no correlations were found and preterm infants' behavioral responses did not seem to differ as a function of gestational age at birth. The fact that our results at younger ages did not find an influence of degree of prematurity challenges the proposal of the possible decrease of the impact of degree of prematurity as infants become older and reach a threshold of linguistic input that would compensate for the immaturity of the organism and the lack of intrauterine exposure to speech. Alternatively, the potential early impact of prematurity might induce cascading effects on linguistic development until childhood and some of these effects might in fact increase with development. Behavioral studies have found delays especially in very preterm children up to school years and brain imaging research has found that neural differences are related to performance (Feldman et al., 2012). Although our findings did not reveal an effect of degree of prematurity (which as null results, have to be considered with care), they point to the importance of further elucidating the contribution of gestational age, along with medical risk on linguistic abilities and subsequent developmental trajectories.

4. Biological factors and brain development

The question of whether there is a threshold at which the brain remains unaffected (or not significantly affected) by preterm birth or whether there is a linear relationship between gestational age and brain development has been recently raised (Lemola et al., 2017). As described in the General Introduction, preterm infants born at lower gestational ages (extremely and very preterm) are more vulnerable to brain injuries (intraventricular hemorrhage, periventricular leukomacia, cerebral palsy, among other lesions; Volpe, 2009). During the last trimester of pregnancy, gyrification begins and neurons go through a process of synaptic maturation, which thus corresponds with

the time when preterm births occur (Luciana, 2003; Vohr, 2014). Brain injuries may interrupt this process and impact normal brain development. Although brain damage is more often observed in extremely and very preterm born infants, moderate and late preterm children also suffer more medical complications and show smaller grey and white matter volume than fullterm children (Boyle & Boyle, 2011; Munakata, et al., 2013; Soria-Pastor et al., 2009).

If brain maturation in preterm infants is gradually reaching a similar state of maturation as in fullterm infants, are differences between preterm and fullterm infants larger in the early stages of development and then decrease as preterm infants overcome maturational constraints? Or are initial differences less evident, for example, in standardized measures, and they become more evident as children grow up and abilities become more complex? Luciana (2003) proposes several developmental courses on the basis of animal studies. The first possibility is that damage is so severe that no recovery occurs. The second is that damage does not hamper normal development. The third one is that injury may affect early stages of development but might recover its function with increasing age. Lastly, the fourth possibility is that dysfunction is less evident or absent in infancy but becomes more evident with age. Again, although these particular circumstances are more frequently found in extremely and very preterm infants, moderate and late preterm birth also interrupts the normal brain development that is expected to take place in the protected womb.

Regarding the development of the auditory system, if the cochlea is functional by 23-25 GWs (Graven & Browne, 2008) and fetuses perceive sounds by 26-28 weeks (Chelli & Chanoufi, 2008), it is possible that we did not find a linear relationship between gestational age and performance because the auditory system was sufficiently developed by the time of birth in most of the preterm infants tested in auditory-only tasks. Nevertheless, it might be that while listening abilities are well preserved, differences in brain structure and extrauterine environmental factors could lead to altered neural processing (Therien et al., 2004) or atypical development (Kamirloff-Smith, 1998; Sansavini et al., 2011). Some recent findings could be consistent with this idea. Although many studies have shown that preterm children with more medical complications (usually extremely/very preterm) tend to have poorer cognitive outcomes (Vohr, 2014; Volpe, 1991), a recent study revealed that 36% of moderate preterm

infants (32-34 GWs) score below threshold values in neurodevelopmental tests between 22 and 26 months maturational age (EPIPAGE 2: Pierrat et al., 2017).

Moreover, in Chapter 2, examining audiovisual perception, we found differential looking patterns between preterm and fullterm infants. The behavior observed could be due to the development of the visual system and how preterm infants encode visual information (Rose et al., 2001). A second possible explanation is that preterm infants encounter more difficulties processing speech and allocate attention differently to fullterm peers. Yet another possibility is that earlier exposure to simultaneous auditory and visual information increases competition among sensory systems, interfering with the normal sequence of biological events and amount of experience, as proposed by Turkewitz and Kenny (1982, 1985).

To summarize, children born very preterm and to a lesser extent those born moderate and late preterm, exhibit lower performance in neurodevelopmental tests than the fullterm population. Unfortunately, these studies often focus on assessment after the first and second year of life. Given its complexity, this topic will deserve further research investigating the potential effect of biological and environmental factors, along with other sociodemographic characteristics, on early and later early developmental outcomes.

5. Strengths and limitations

The strengths in this dissertation are that it provides new evidence on early speech perception in the whole range of prematurity, from extremely-to-late preterm infants. In the last decades, important advances have led to increasing survival rates of preterm born infants, in particular of those born extremely and very preterm, but moderate and late preterm infants account for the greatest proportion of preterm births. Programs for infants at risk for disabilities and developmental delays have increased in the last decades. However, little research to date has investigated early language acquisition in very preterm infants and even fewer studies have included moderate and late preterm infants, although both subgroups are at risk for later linguistic deficits and academic difficulties (Mulder et al., 2010; Pritchard et al., 2009; Putnick et al., 2017). Our research has also contributed new data to preterm infants' abilities in different language domains. Furthermore, different processes of language

acquisition have been studied from the onset of lexical acquisition through 2 years, the age at which preterm toddlers are usually reported to present receptive and expressive vocabulary delays when evaluated with standardized tests in clinical practice (for a review, see Vohr 2016).

The current research also has some clear limitations. The first involves methodological considerations. The HPP procedure was chosen in many of the experiments to allow comparison with previous data on fullterm infants tested under the same conditions. However, this method requires a certain degree of motor skills that many of the preterm infants tested at 6 months postnatal age might not have developed, as reflected by the high rejection rates in Experiments 1 and 3. Although the comparisons between included and excluded infants did not reveal significant differences, we observed that excluded infants tended to have lower neonatal scores and birth weights and longer hospital stays than included infants. For this reason, the findings reported might only correspond to the healthiest and “high-functioning” preterm infants at lower risks for later developmental outcomes. Due to recruitment limitations (preterm infants were recruited through three different sources: hospital, parents’ association of preterm infants, and birth lists issued by the city registry office), full-descriptive statistics for birth history and medical risk were not possible. Future collaborations between medical staff and developmental researchers is encouraged to develop an index of risk for medical complications that could be used to provide more objective and quantitative measures for use in research practice.

A second limitation is the size of the samples. Although the size of each preterm group was similar (or will be at completion of each experiment) to standard practice in developmental research, larger samples would be needed to have better insights into the role of different medical and environmental factors, and then plan intervention programs accordingly. Moreover, our groups were constituted of unbalanced number of participants in terms of extremely/very versus moderate/late preterms in several experiments, which weakens the analyses of the degree of prematurity. Extremely and very preterm infants were more difficult to recruit because this subgroup accounts for a smallest proportion of preterm birth. In France extremely and very preterm infants represented 15% of preterm births in 2010 while moderate and late preterm infants represented 85% (Institut National de la Santé et de la Recherche Médicale). In addition, because very preterm infants are at risk for diverse

complications and consequently are monitored closely by their pediatricians, parents of these children often have less expendable time with which to voluntarily participate in research studies. Again, this highlights the need to establish closer collaborations between clinical and research practice so that present and future generations of children born prematurely can benefit to a larger extent from possible interventions.

A third limitation of the present research is that for most abilities we investigated, preterm infants were only tested at postnatal age, at which these abilities are found in fullterm infants, and no data is available for their performance at maturational age. However, groups of fullterm infants matching on maturational age with the preterm groups were included in Experiments 2 (monosyllabic word segmentation) and 6 (visual scanning of audiovisual speech) to explore possible developmental trajectories. Moreover, in Experiment 8, word production was compared to normative data according to preterm children's postnatal and maturational ages. Ideally, one-to-one matching on the basis of postnatal age, gender, and SES would have provided better control groups (Adams et al., 2017).

Furthermore, although we originally planned to follow children longitudinally to examine the possible relationship between early speech perception and later outcomes, this was not possible due to recruitment limitations. For all these reasons, the generalizability of the present findings is limited to preterm children that are high functioning, especially for the results of Chapter 1. The results of Chapter 2 and 3 mostly concern the abilities of moderate and late preterm infants who constituted the majority of the infants included.

6. Future directions

The present research has provided evidence of preterm infants' abilities tested at the postnatal age on different language subdomains. Further research on several topics is needed to further shed light on the possible effects of prematurity on the different language subdomains.

Regarding gestational age, the segmentation experiments in Chapter 1 failed to show that it was related to performance. Moreover, Chapters 2 and 3 included a majority of moderate and late preterm infants. Enlarging sample size by including more participants in each subgroup will provide more statistical power towards identifying

possible effects of degree of prematurity. The current study is only a first step in the effort to explore these abilities in all preterm infants in link with their gestational age at birth. Importantly, the whole range of preterm infants is more prone to cognitive deficits than fullterm infants during development.

With respect to segmentation abilities, future studies are needed to investigate when and how preterm infants segment more complex words in French. Studying segmentation abilities using other methods (EEG, NIRS, eye-tracking), will show if the underlying neural bases between preterm and fullterm populations differ. As previously discussed, studies on the emergence of segmentation abilities in stress-based languages will also provide very valuable knowledge as to how lack of intrauterine exposition to low frequency speech sounds might have an impact on linguistic development. However, although the interest of the first studies exploring this particular issue aimed at exploring whether certain abilities in language acquisition are “experience-dependent” or maturationally constraint, we suggest that there is an additional aim in this research, namely, to specify the differential effect of prematurity in different linguistic domains, taking into account other factors that might affect linguistic development in this population. For instance, including more detailed medical information and characteristics of preterms’ environment might allow to detect children that might need intervention and support. For cognitive development in general and language acquisition in particular, it would be very valuable to evaluate environmental information/factors such as duration of stay in the incubator, parental input during NICU stay (Rand & Lahav, 2014), measures of ambient noise in the NICU (Kuhn et al., 2012) as well as other measures that have been related to language development, such as parents’ educational level or socioeconomic status (Fernald et al., 2013).

The last factors previously mentioned involve face-to-face human interactions which should be particularly relevant in future investigations on audiovisual speech perception abilities in preterm infants. As an example, Caskey, Stephens, Tucker, and Vohr (2011) found that infants produced more vocalizations, in terms of conversational turns, when one of their parents was present in the NICU than in their absence. Moreover, in a following study, Caskey and colleagues (2014) demonstrated that increased amount of parent talk in the NICU is associated to higher neurodevelopmental outcomes at 7 and 8 months maturational age. This indicates that interactions, in such fragile organisms, can have a powerful effect, boosting their

linguistic abilities. It remains to be further explored how these factors could interact with attention to different facial cues in audiovisual speech perception or in other abilities related to the matching of temporal cues, such as phonological and word learning.

As we found evidence for recognition of familiar word-forms at 11 months of postnatal age in moderate and late preterm infants, future word recognition tasks could explore whether this subgroup shows slower processing speed, as has been reported for very preterms (Marchman et al., 2016; Ramon-Casas et al., 2013) or whether they follow a developmental course closer to fullterm toddlers. It would be interesting to determine whether a linear relationship between processing speed and gestational age exists in word recognition studies. If such relationship were found, it could contribute to explain why children born moderate and late preterm do not differ in lexical performance from fullterm children at the age of 2 but children born extremely preterm and, to a lesser extent, children born very preterm, obtain lower scores than their fullterm peers (Kern & Gayraud, 2007; Sansavini, Guarini, Alessandroni, Faldella et al., 2006).

7. General conclusion

To conclude, Figure 4.0. places the main results from the present research work within the current knowledge on “healthy” preterm infants’ language developmental trajectory in the first two years of life.

Based on the milestones reported in fullterm infants and the present results in preterm infants tested at the same postnatal age, it can be concluded that prematurity does not equally affect all linguistic subdomains and that health status may play a role in the development of speech perception abilities. For segmentation abilities, preterm infants were found to perform as their fullterm peers at the same postnatal age; however, these results might only apply to high-functioning preterm infants and easy-to-segment word forms. For audiovisual speech perception, it was found that, compared to fullterm infants who showed different scanning patterns of a face speaking in two different languages (native versus non-native), preterm infants showed similar scanning patterns for both languages. These differential gaze patterns provide a first step to characterize the developmental course of audiovisual speech perception in (mostly moderate/late) preterm infants. For recognition of familiar word-forms, (mostly moderate/late) preterm infants showed successful recognition at 11 months postnatal

age, similarly to their fullterm peers. Lastly, for word production at around 24 months of postnatal age, we found that preterm infants have smaller vocabularies than fullterms of the same postnatal age, but as a group, have similar levels as their fullterm, maturational age peers. However, more preterm infants were below the 10th percentile than expected based on (fullterm) norms for both postnatal and maturational age, which might constitute an index for the early identification of (preterm) infants at risk for linguistic delays. Future research following extremely-to-late preterm infants longitudinally are encouraged to better specify their linguistic developmental trajectory.

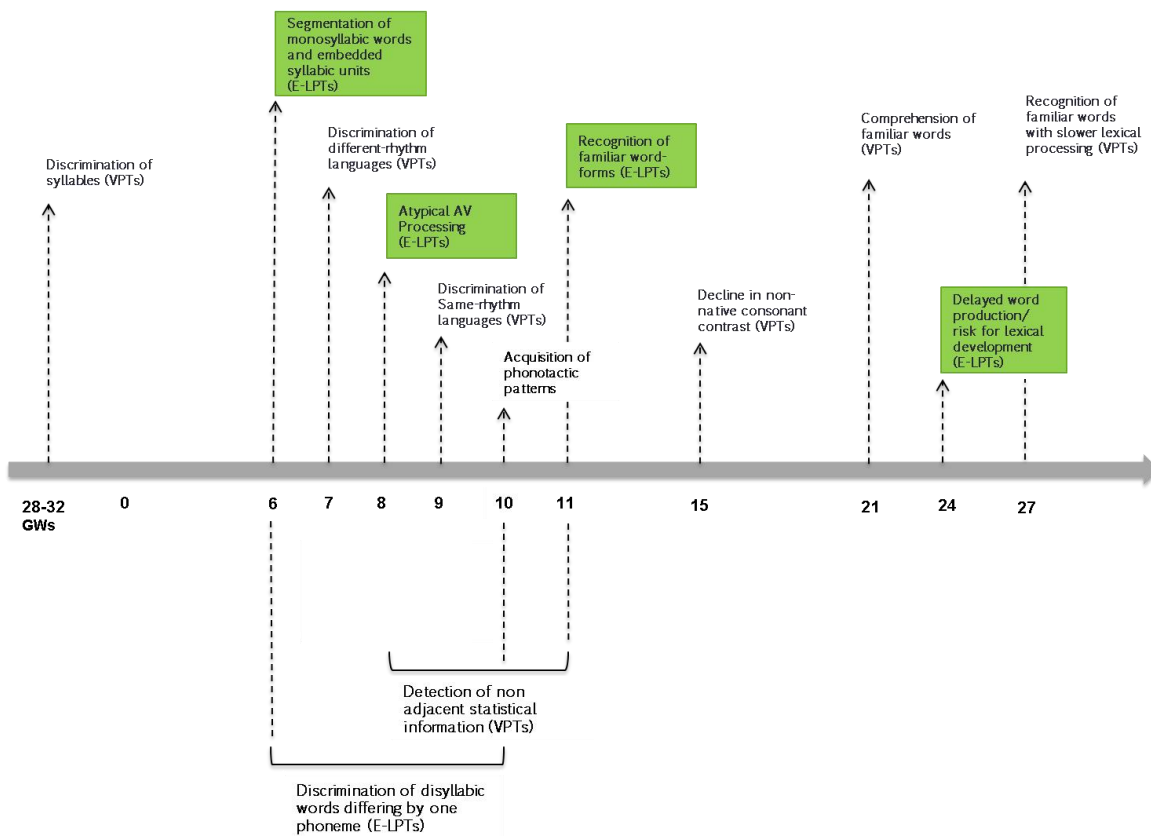


Figure 4.0. Towards specifying the trajectory of early language acquisition in preterm infants at postnatal age. E-LPTs = extremely-to-late preterm infants; VPT = very preterm infants.

REFERENCES

- Aarnoudse-Moens, C. S. H., Weisglas-Kuperus, N., Duivenvoorden, H. J., Oosterlaan, J., & Goudoever, J. B. (2013). Neonatal and parental predictors of executive function in very preterm children. *Acta Paediatrica*, *102*(3), 282-286.
- Aarnoudse-Moens, C.S.H., Duivenvoorden, H.J., Weisglas-Kuperus, N., Van Goudoever, J.B., & Oosterlaan, J. (2012). The profile of executive function in very preterm children at 4 to 12 years. *Developmental Medicine and Child Neurology*, *54*(3), 247-253.
- Abboub, N., Bijeljac-Babic, R., Serres, J., & Nazzi, T. (2015). On the importance of being bilingual: Word stress processing in a context of segmental variability. *Journal of experimental child psychology*, *132*, 111-120.
- Abboub, N., Nazzi, T., & Gervain, J. (2016). Prosodic grouping at birth. *Brain and Language*, *162*, 46-59.
- Abercrombie, D. (1967). Elements of general phonetics. Edinburgh: University of Edinburgh Press.
- Adams, K. A., Marchman, V. A., Loi, E. C., Ashland, M. D., Fernald, A., & Feldman, H. M. (2017). Caregiver Talk and Medical Risk as Predictors of Language Outcomes in Full Term and Preterm Toddlers. *Child Development*.
- Adams-Chapman, I., Bann, C., Carter, S. L., Stoll, B. J., & NICHD Neonatal Research Network. (2015). Language outcomes among ELBW infants in early childhood. *Early human development*, *91*(6), 373-379.
- Ajayi-Obe, M., Saeed, N., Cowan, F. M., Rutherford, M. A., & Edwards, A. D. (2000). Reduced development of cerebral cortex in extremely preterm infants. *The Lancet*, *356*(9236), 1162-1163.
- Altwater-Mackensen, N., & Grossmann, T. (2015). Learning to match auditory and visual speech cues: Social influences on acquisition of phonological categories. *Child development*, *86*(2), 362-378.
- Altwater-Mackensen, N., & Mani, N. (2013). Word-form familiarity bootstraps infant speech segmentation. *Developmental science*, *16*(6), 980-990.
- Anjari, M., Counsell, S. J., Srinivasan, L., Allsop, J. M., Hajnal, J. V., Rutherford, M. A., & Edwards, A. D. (2009). The association of lung disease with cerebral white matter abnormalities in preterm infants. *Pediatrics*, *124*(1), 268-276.
- Arabin, B. (2002). Music during pregnancy. *Ultrasound in Obstetrics & Gynecology*, *20*(5), 425-430.

- Armstrong, E., Schleicher, A., Omran, H., Curtis, M., & Zilles, K. (1995). The ontogeny of human gyrification. *Cerebral cortex*, *5*(1), 56-63.
- Aslin, R. N., Saffran, J. R., & Newport, E. L. (1998). Computation of conditional probability statistics by 8-month-old infants. *Psychological science*, *9*(4), 321-324.
- Atelier Parisien d'Urbanisme. Website accessed 27/09/2017:http://www.apur.org/sites/default/files/documents/Note80_metropole_cosmopolite.pdf
- Aylward, G. P. (2002). Cognitive and neuropsychological outcomes: more than IQ scores. *Developmental Disabilities Research Reviews*, *8*(4), 234-240.
- Aylward, G. P. (2005). Neurodevelopmental outcomes of infants born prematurely. *Journal of Developmental & Behavioral Pediatrics*, *26*(6), 427-440.
- Aylward, G.P. (2014). Update on neurodevelopmental outcomes of infants born prematurely. *Journal of Developmental & Behavioral Pediatrics*, *35*(6), 392-393.
- Bahrack, L. E. (1992). Infants' perceptual differentiation of amodal and modality-specific audio-visual relations. *Journal of Experimental Child Psychology*, *53*, 197-209.
- Bahrack, L. E., Hernandez-Reif, M., & Flom, R. (2005). The development of infant learning about specific face-voice relations. *Developmental psychology*, *41*(3), 541.
- Baker, C. I., Olson, C. R., & Behrmann, M. (2004). Role of attention and perceptual grouping in visual statistical learning. *Psychological Science*, *15*(7), 460-466.
- Balaban, M. T., & Waxman, S. R. (1997). Do words facilitate object categorization in 9-month-old infants?. *Journal of experimental child psychology*, *64*(1), 3-26.
- Baldwin, D. A., & Moses, L. J. (2001). Links between social understanding and early word learning: Challenges to current accounts. *Social Development*, *10*(3), 309-329.
- Ball, G., Boardman, J. P., Aljabar, P., Pandit, A., Arichi, T., Merchant, N., ... & Counsell, S. J. (2013). The influence of preterm birth on the developing thalamocortical connectome. *Cortex*, *49*(6), 1711-1721.
- Barde, L. H., Yeatman, J. D., Lee, E. S., Glover, G., & Feldman, H. M. (2012). Differences in neural activation between preterm and full term born adolescents on a sentence comprehension task: implications for educational accommodations. *Developmental cognitive neuroscience*, *2*, S114-S128.
- Barenholtz, E., Mavica, L., & Lewkowicz, D. J. (2016). Language familiarity modulates relative attention to the eyes and mouth of a talker. *Cognition*, *147*, 100-105.

- Barre, N., Morgan, A., Doyle, L. W., & Anderson, P. J. (2011). Language abilities in children who were very preterm and/or very low birth weight: a meta-analysis. *The Journal of pediatrics*, 158(5), 766-774.
- Barrera, M. E., Rosenbaum, P. L., & Cunningham, C. E. (1987). Corrected and uncorrected Bayley scores: Longitudinal developmental patterns in low and high birth weight preterm infants. *Infant Behavior and development*, 10(3), 337-346.
- Bates, E., Dale, P. S., & Thal, D. (1995). Individual differences and their implications for theories of language development. *The handbook of child language*, 96-151.
- Bayley, N. (1969). Manual for the Bayley scales of infant development. Psychological Corporation.
- Beauchemin, M., González-Frankenberger, B., Tremblay, J., Vannasing, P., Martínez-Montes, E., Belin, P., ... & Lassonde, M. (2010). Mother and stranger: an electrophysiological study of voice processing in newborns. *Cerebral cortex*, 21(8), 1705-1711.
- Beck, S., Wojdyla, D., Say, L., Betran, A. P., Merialdi, M., Requejo, J. H., ... & Van Look, P. F. (2010). The worldwide incidence of preterm birth: a systematic review of maternal mortality and morbidity. *Bulletin of the World Health Organization*, 88(1), 31-38.
- Bedford, R., Elsabbagh, M., Gliga, T., Pickles, A., Senju, A., Charman, T., & Johnson, M. H. (2012). Precursors to social and communication difficulties in infants at-risk for autism: Gaze following and attentional engagement. *Journal of autism and developmental disorders*, 42(10), 2208-2218.
- Benavides-Varela, S., Hochmann, J. R., Macagno, F., Nespor, M., & Mehler, J. (2012). Newborn's brain activity signals the origin of word memories. *Proceedings of the National Academy of Sciences*, 109(44), 17908-17913.
- Bergelson, E., & Swingle, D. (2012). At 6–9 months, human infants know the meanings of many common nouns. *Proceedings of the National Academy of Sciences*, 109(9), 3253-3258.
- Bergmann, C., & Cristia, A. (2016). Development of infants' segmentation of words from native speech: a meta-analytic approach. *Developmental science*, 19(6), 901-917.
- Bertoncini, J., Bijeljac-Babic, R., Blumstein, S. E., & Mehler, J. (1987). Discrimination in neonates of very short CVs. *The Journal of the Acoustical Society of America*, 82(1), 31-37.

- Bertoncini, J., Bijeljac-Babic, R., Jusczyk, P. W., Kennedy, L. J., & Mehler, J. (1988). An investigation of young infants' perceptual representations of speech sounds. *Journal of experimental psychology: General*, *117*(1), 21.
- Bertoncini, J., Floccia, C., Nazzi, T., & Mehler, J. (1995). Morae and syllables: Rhythmical basis of speech representations in neonates. *Language and speech*, *38*(4), 311-329.
- Best, C. T., McRoberts, G. W., & Sithole, N. N. (1988). The phonological basis of perceptual loss for non-native contrasts: Maintenance of discrimination among Zulu clicks by English-speaking adults and infants. *Journal of Experimental Psychology: human perception and performance*, *14*(3), 345-360.
- Bialystok, E., & Feng, X. (2009). Language proficiency and executive control in proactive interference: Evidence from monolingual and bilingual children and adults. *Brain and language*, *109*(2), 93-100.
- Bialystok, E., & Viswanathan, M. (2009). Components of executive control with advantages for bilingual children in two cultures. *Cognition*, *112*(3), 494-500.
- Bijeljac-Babic, R., Bertoncini, J., & Mehler, J. (1993). How do 4-day-old infants categorize multisyllabic utterances?. *Developmental Psychology*, *29*(4), 711.
- Bijeljac-Babic, R., Höhle, B., & Nazzi, T. (2016). Early prosodic acquisition in bilingual infants: the case of the perceptual trochaic bias. *Frontiers in psychology*, *7*.
- Bijeljac-Babic, R., Serres, J., Höhle, B., & Nazzi, T. (2012). Effect of bilingualism on lexical stress pattern discrimination in French-learning infants. *PLoS One*, *7*(2), e30843.
- Blackburn, S. (2016). Brain Injury in Preterm Infants: Pathogenesis and Nursing Implications. *Newborn and Infant Nursing Reviews*, *16*(1), 8-12.
- Blencowe, H., Cousens, S., Oestergaard, M. Z., Chou, D., Moller, A. B., Narwal, R., ... & Lawn, J. E. (2012). National, regional, and worldwide estimates of preterm birth rates in the year 2010 with time trends since 1990 for selected countries: a systematic analysis and implications. *The Lancet*, *379*(9832), 2162-2172.
- Blondel, B., Macfarlane, A., Gissler, M., Breart, G., & Zeitlin, J. (2006). General obstetrics: Preterm birth and multiple pregnancy in European countries participating in the PERISTAT project. *BJOG: An International Journal of Obstetrics & Gynaecology*, *113*(5), 528-535.
- Bloom, L. (1976). One word at a time: The use of single word utterances before syntax (Vol. 154). Walter de Gruyter.

- Bonatti, L. L., Pena, M., Nespor, M., & Mehler, J. (2005). Linguistic constraints on statistical computations: The role of consonants and vowels in continuous speech processing. *Psychological Science, 16*(6), 451-459.
- Boothe, R. G., Dobson, V., & Teller, D. Y. (1985). Postnatal development of vision in human and nonhuman primates. *Annual review of neuroscience, 8*(1), 495-545.
- Bortfeld, H., Morgan, J. L., Golinkoff, R. M., & Rathbun, K. (2005). Mommy and me: Familiar names help launch babies into speech-stream segmentation. *Psychological science, 16*(4), 298-304.
- Bosch, L. (2011). Precursors to language in preterm infants: speech perception abilities in the first year of life. In O. Braddick, J., Atkinson & G.M. Innocenti, (Eds.), *Progress in Brain Research* (pp. 239-257). Burlington: Academic Press.
- Bosch, L., Figueras, M., Teixidó, M., & Ramon-Casas, M. (2013). Rapid gains in segmenting fluent speech when words match the rhythmic unit: evidence from infants acquiring syllable-timed languages. *Frontiers in psychology, 4*.
- Bosch, L., & Sebastián-Gallés, N. (1997). Native-language recognition abilities in 4-month-old infants from monolingual and bilingual environments. *Cognition, 65*(1), 33-69.
- Bosch, L., & Sebastián-Gallés, N. (2001). Evidence of early language discrimination abilities in infants from bilingual environments. *Infancy, 2*(1), 29-49.
- Bosch, L., & Sebastián-Gallés, N. (2003). Simultaneous bilingualism and the perception of a language-specific vowel contrast in the first year of life. *Language and speech, 46*(2-3), 217-243.
- Bouchon, C., Floccia, C., Fux, T., Adda-Decker, M., & Nazzi, T. (2015). Call me Alix, not Elix: vowels are more important than consonants in own-name recognition at 5 months. *Developmental science, 18*(4), 587-598.
- Boyle, J. D., & Boyle, E. M. (2011). Born just a few weeks early: does it matter?. *Archives of Disease in Childhood-Fetal and Neonatal Edition, fetalneonatal-2011*.
- Braginsky, M., Yurovsky, D., Marchman, V. A., & Frank, M. C. (2016). From uh-oh to tomorrow: Predicting age of acquisition for early words across languages. In *Proceedings of the 38th Annual Meeting of the Cognitive Science Society*, Austin, TX.

- Briscoe, J., Gathercole, S.E., & Marlow, N. (1998). Short-term memory and language outcomes after extreme prematurity at birth. *Journal of Speech, Language, and Hearing Research, 41*(3), 654-666.
- Brookes, H., Slater, A., Quinn, P. C., Lewkowicz, D. J., Hayes, R., & Brown, E. (2001). Three-month-old infants learn arbitrary auditory-visual pairings between voices and faces. *Infant and Child Development, 10*(1-2), 75-82.
- Brooks, R., & Meltzoff, A. N. (2005). The development of gaze following and its relation to language. *Developmental science, 8*(6), 535-543.
- Brooks, R., & Meltzoff, A. N. (2008). Infant gaze following and pointing predict accelerated vocabulary growth through two years of age: A longitudinal, growth curve modeling study. *Journal of child language, 35*(1), 207-220.
- Buchan, J. N., Paré, M., & Munhall, K. G. (2007). Spatial statistics of gaze fixations during dynamic face processing. *Social Neuroscience, 2*(1), 1-13.
- Bushnell, I. W. R. (2001). Mother's face recognition in newborn infants: Learning and memory. *Infant and Child Development, 10*(1-2), 67-74.
- Byers-Heinlein, K., & Fennell, C. T. (2014). Perceptual narrowing in the context of increased variation: insights from bilingual infants. *Developmental Psychobiology, 56*(2), 274-291.
- Byers-Heinlein, K., Burns, T. C., & Werker, J. F. (2010). The roots of bilingualism in newborns. *Psychological science, 21*(3), 343-348.
- Caldara, R., & Mielle, S. (2011). iMap: A novel method for statistical fixation mapping of eye movement data. *Behavior Research Methods, 43*, 864-878.
- Caravale, B., Tozzi, C., Albino, G., & Vicari, S. (2005). Cognitive development in low risk preterm infants at 3-4 years of life. *Archives of Disease in Childhood-Fetal and Neonatal Edition, 90*(6), F474-F479.
- Carpenter, M., Nagell, K., Tomasello, M., Butterworth, G., & Moore, C. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the society for research in child development, i*-174.
- Caskey, M., Stephens, B., Tucker, R., & Vohr, B. (2011). Importance of parent talk on the development of preterm infant vocalizations. *Pediatrics, 128*(5), 910-916.
- Caskey, M., Stephens, B., Tucker, R., & Vohr, B. (2014). Adult talk in the NICU with preterm infants and developmental outcomes. *Pediatrics, 133*(3), e578-e584.
- Cattani, A., Bonifacio, S., Fertz, M., Iverson, J. M., Zocconi, E., & Caselli, M. C. (2010). Communicative and linguistic development in preterm children: a longitudinal

- study from 12 to 24 months. *International journal of language & communication disorders*, 45(2), 162-173.
- Chan, E., & Quigley, M.A. (2014). School performance at age 7 years in late preterm and early preterm birth: a cohort study. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, 99(6), 451-457.
- Charollais, A., Stumpf, M. H., De Quelen, R., Rondeau, S., Pasquet, F., & Marret, S. (2014). Delayed language development at two years of age in very preterm infants in the Perinatal Network of Haute-Normandie. *Early human development*, 90(12), 891.
- Chelli, D., & Chanoufi, B. (2008). Fetal audition. Myth or reality. *Journal de gynécologie, obstétrique et biologie de la reproduction*, 37(6), 554-558.
- Chomsky N. (1965). *Aspects of the Theory of Syntax*. Cambridge, MIT Press.
- Christophe, A., Dupoux, E., Bertoncini, J., & Mehler, J. (1994). Do infants perceive word boundaries? An empirical study of the bootstrapping of lexical acquisition. *The Journal of the Acoustical Society of America*, 95(3), 1570-1580.
- Christophe, A., Mehler, J., & Sebastián-Gallés, N. (2001). Perception of prosodic boundary correlates by newborn infants. *Infancy*, 2(3), 385-394.
- Chyi, L. J., Lee, H. C., Hintz, S. R., Gould, J. B., & Sutcliffe, T. L. (2008). School outcomes of late preterm infants: special needs and challenges for infants born at 32 to 36 weeks gestation. *The Journal of pediatrics*, 153(1), 25-31.
- Conboy, B. T., Brooks, R., Meltzoff, A. N., & Kuhl, P. K. (2015). Social Interaction in Infants' Learning of Second-Language Phonetics: An Exploration of Brain-Behavior Relations. *Developmental neuropsychology*, 40(4), 216-229.
- Constable, R. T., Vohr, B. R., Scheinost, D., Benjamin, J. R., Fulbright, R. K., Lacadie, C., ... & Ment, L. R. (2013). A left cerebellar pathway mediates language in prematurely-born young adults. *Neuroimage*, 64, 371-378.
- Coulon, M., Guellai, B., & Streri, A. (2011). Recognition of unfamiliar talking faces at birth. *International Journal of Behavioral Development*, 35(3), 282-287.
- Curtiss, S. (1977). *Genie*. John Wiley & Sons, Inc..
- Cutler, A., & Carter, D. M. (1987). The predominance of strong initial syllables in the English vocabulary. *Computer Speech & Language*, 2(3-4), 133-142.
- Cutler, A., & Norris, D. (1988). The role of strong syllables in segmentation for lexical access. *Journal of Experimental Psychology: Human perception and performance*, 14(1), 113-121.

- Cutler, A., Mehler, J., Norris, D., & Segui, J. (1989). Limits on bilingualism. *Nature*, *340*(6230), 229-230.
- De Jong, M., Verhoeven, M., & van Baar, A. L. (2012). School outcome, cognitive functioning, and behaviour problems in moderate and late preterm children and adults: a review. In *Seminars in Fetal and Neonatal Medicine*, *17*(3), 163-169. WB Saunders.
- de Kievet, J. F., Zoetebier, L., Van Elburg, R. M., Vermeulen, R. J., & Oosterlaan, J. (2012). Brain development of very preterm and very low-birthweight children in childhood and adolescence: a meta-analysis. *Developmental Medicine & Child Neurology*, *54*(4), 313-323.
- de Saussure, F. (1916). Nature of the linguistic sign. In: Bally, C. and Sechehaye, A. eds. *Cours de linguistique générale*. New York: McGraw Hill Education.
- DeCasper, A. J., & Fifer, W. P. (1980). Of human bonding: newborns prefer their mother's voice. *Science*, *208*(4448), 1174-1176.
- DeCasper, A. J., & Fifer, W. P. (2004). Of human bonding: Newborns prefer their mothers' voices. *Readings on the Development of Children*, M. Gauvain and M. Cole, Eds. Worth Publishers, 56.
- DeCasper, A. J., & Spence, M. J. (1986). Prenatal maternal speech influences newborns' perception of speech sounds. *Infant behavior and Development*, *9*(2), 133-150.
- Dehaene-Lambertz, G., & Spelke, E. S. (2015). The infancy of the human brain. *Neuron*, *88*(1), 93-109.
- Delle Luche, C., Floccia, C., Granjon, L., & Nazzi, T. (2017). Infants' First Words are not Phonetically Specified: Own Name Recognition in British English-Learning 5-Month-Olds. *Infancy*, *22*(3), 362-388.
- Delle Luche, C., Poltrock, S., Goslin, J., New, B., Floccia, C., & Nazzi, T. (2014). Differential processing of consonants and vowels in the auditory modality: A cross-linguistic study. *Journal of Memory and Language*, *72*, 1-15.
- Delobel-Ayoub, M., Arnaud, C., White-Koning, M., Casper, C., Pierrat, V., Garel, M., ... & Kaminski, M. (2009). Behavioral problems and cognitive performance at 5 years of age after very preterm birth: the EPIPAGE Study. *Pediatrics*, *123*(6), 1485-1492.
- DePaolis, R. A., Vihman, M. M., & Keren-Portnoy, T. (2011). Do production patterns influence the processing of speech in prelinguistic infants?. *Infant Behavior and Development*, *34*(4), 590-601.

- deRegnier, R. A., Wewerka, S., Georgieff, M. K., Mattia, F., & Nelson, C. A. (2002). Influences of postconceptional age and postnatal experience on the development of auditory recognition memory in the newborn infant. *Developmental psychobiology*, *41*(3), 216-225.
- Dodd, B. (1979). Lip reading in infants: Attention to speech presented in-and out-of-synchrony. *Cognitive psychology*, *11*(4), 478-484.
- D'Odorico, L., Majorano, M., Fasolo, M., Salerni, N., & Suttora, C. (2011). Characteristics of phonological development as a risk factor for language development in Italian-speaking pre-term children: A longitudinal study. *Clinical Linguistics & Phonetics*, *25*(1), 53-65.
- Draganova, R., Eswaran, H., Murphy, P., Huotilainen, M., Lowery, C., & Preissl, H. (2005). Sound frequency change detection in fetuses and newborns, a magnetoencephalographic study. *Neuroimage*, *28*(2), 354-361.
- Dubois, J., Dehaene-Lambertz, G., Soares, C., Cointepas, Y., Le Bihan, D., & Hertz-Pannier, L. (2008). Microstructural correlates of infant functional development: example of the visual pathways. *Journal of Neuroscience*, *28*(8), 1943-1948.
- Eimas, P. D., Siqueland, E. R., Jusczyk, P., & Vigorito, J. (1971). Speech perception in infants. *Science*, *171*(3968), 303-306.
- Elman, J. L., Bates, E. A., Johnson, M. H., Karmiloff-Smith, A., Parisi, D., & Plunkett, K. (1996). Rethinking innateness. Cambridge, MA: MIT Press.
- Engelhardt, E., Inder, T. E., Alexopoulos, D., Dierker, D. L., Hill, J., Essen, D., & Neil, J. J. (2015). Regional impairments of cortical folding in premature infants. *Annals of neurology*, *77*(1), 154-162.
- Fallang, B., Saugstad, O.D., Grøgaard, J., & Hadders-Algra, M. (2003). Kinematic quality of reaching movements in preterm infants. *Pediatric research*, *53*(5), 836-842.
- Farroni, T., Csibra, G., Simion, F., & Johnson, M. H. (2002). Eye contact detection in humans from birth. *Proceedings of the National Academy of Sciences*, *99*(14), 9602-9605.
- Feldman, H. M., Lee, E. S., Yeatman, J. D., & Yeom, K. W. (2012). Language and reading skills in school-aged children and adolescents born preterm are associated with white matter properties on diffusion tensor imaging. *Neuropsychologia*, *50*(14), 3348-3362.

- Fenson, L., Bates, E., Dale, P. S., Marchman, V. A., Reznick, J. S., & Thal, D. J. (2007). MacArthur-Bates communicative development inventories. Paul H. Brookes Publishing Company.
- Ferguson, B., Havy, M., & Waxman, S. R. (2015). The precision of 12-month-old infants' link between language and categorization predicts vocabulary size at 12 and 18 months. *Frontiers in psychology, 6*.
- Fernald, A., & Marchman, V. A. (2012). Individual differences in lexical processing at 18 months predict vocabulary growth in typically developing and late-talking toddlers. *Child development, 83*(1), 203-222.
- Fernald, A., Marchman, V. A., & Weisleder, A. (2013). SES differences in language processing skill and vocabulary are evident at 18 months. *Developmental science, 16*(2), 234-248.
- Fernald, A., Perfors, A., & Marchman, V. A. (2006). Picking up speed in understanding: Speech processing efficiency and vocabulary growth across the 2nd year. *Developmental psychology, 42*(1), 98.
- Fernald, A., Zangl, R., Portillo, A. L., & Marchman, V. A. (2008). Looking while listening: Using eye movements to monitor spoken language. *Developmental psycholinguistics: On-line methods in children's language processing, 44*, 97.
- Ferry, A. L., Hespos, S. J., & Waxman, S. R. (2010). Categorization in 3-and 4-month-old infants: an advantage of words over tones. *Child development, 81*(2), 472-479.
- Fifer, W. P., & Moon, C. (1989). Psychobiology of newborn auditory preferences. *Seminars in Perinatology, 13*, 430-433.
- Figueras Montiu, M., & Bosch Galceran, L. (2010). Capacidades de discriminación fonética de un contraste vocálico nativo en el prematuro. *Psicothema, 22*(4).
- Floccia, C., Keren-Portnoy, T., DePaolis, R., Duffy, H., Delle Luche, C., Durrant, S., ... & Vihman, M. (2016). British English infants segment words only with exaggerated infant-directed speech stimuli. *Cognition, 148*, 1-9.
- Floccia, C., Nazzi, T., Delle Luche, C., Poltrock, S., & Goslin, J. (2014). English-learning one-to two-year-olds do not show a consonant bias in word learning. *Journal of Child Language, 41*(5), 1085-1114.
- Fort, M., Martin, A., & Peperkamp, S. (2015). Consonants are more important than vowels in the Bouba-kiki effect. *Language and Speech, 58*(2), 247-266.

- Foster-Cohen, S. H., Edgin, J. O., Champion, P. R., & Woodward, L. J. (2007). Early delayed language development in very preterm infants: evidence from the MacArthur-Bates CDI. *Journal of child language*, *34*(3), 655-675.
- Foster-Cohen, S. H., Friesen, M. D., Champion, P. R., & Woodward, L. J. (2010). High prevalence/low severity language delay in preschool children born very preterm. *Journal of Developmental & Behavioral Pediatrics*, *31*(8), 658-667.
- Friederici, A. D., & Wessels, J. M. (1993). Phonotactic knowledge of word boundaries and its use in infant speech perception. *Attention, Perception, & Psychophysics*, *54*(3), 287-295.
- Friederici, A. D., Friedrich, M., & Christophe, A. (2007). Brain responses in 4-month-old infants are already language specific. *Current Biology*, *17*(14), 1208-1211.
- Fulkerson, A. L., & Waxman, S. R. (2007). Words (but not tones) facilitate object categorization: Evidence from 6-and 12-month-olds. *Cognition*, *105*(1), 218-228.
- Gathercole, V. C. M., & Thomas, E. M. (2009). Bilingual first-language development: Dominant language takeover, threatened minority language take-up. *Bilingualism: Language and Cognition*, *12*(2), 213-237.
- Gauthier, S. M., Bauer, C. R., Messinger, D. S., & Cloisus, J. M. (1999). The bayley scales of infant development II: where to start?. *Journal of Developmental & Behavioral Pediatrics*, *20*(2), 75-79.
- Gayraud, F., & Kern, S. (2007). Influence of preterm birth on early lexical and grammatical acquisition. *First Language*, *27*(2), 159-173.
- Gervain, J. (2015). Plasticity in early language acquisition: the effects of prenatal and early childhood experience. *Current opinion in neurobiology*, *35*, 13-20.
- Gervain, J., Macagno, F., Cogoi, S., Peña, M., & Mehler, J. (2008). The neonate brain detects speech structure. *Proceedings of the National Academy of Sciences*, *105*(37), 14222-14227.
- Giménez, M., Miranda, M. J., Born, A. P., Nagy, Z., Rostrup, E., & Jernigan, T. L. (2008). Accelerated cerebral white matter development in preterm infants: a voxel-based morphometry study with diffusion tensor MR imaging. *Neuroimage*, *41*(3), 728-734.
- Gogate, L. J., & Bahrick, L. E. (2001). Intersensory Redundancy and 7-Month-Old Infants' Memory for Arbitrary Syllable-Object Relations. *Infancy*, *2*(2), 219-231.
- Gogate, L. J., & Hollich, G. (2010). Invariance detection within an interactive system: A perceptual gateway to language development. *Psychological review*, *117*(2), 496.

- Gogate, L., Maganti, M., & Perenyi, A. (2014). Preterm and term infants' perception of temporally coordinated syllable-object pairings: Implications for lexical development. *Journal of Speech, Language, and Hearing Research, 57*(1), 187-198.
- Goldfield, B. A., & Reznick, J. S. (1990). Early lexical acquisition: Rate, content, and the vocabulary spurt. *Journal of child language, 17*(1), 171-183.
- Gole, G. A., Ells, A. L., Katz, X., Holmstrom, G., Fielder, A. R., Capone Jr, A., ... & Palmer, E. A. (2005). The international classification of retinopathy of prematurity revisited. *JAMA Ophthalmology, 123*(7), 991-999.
- Golinkoff, R. M., & Hirsh-Pasek, K. (2006). Baby wordsmith: From associationist to social sophisticate. *Current Directions in Psychological Science, 15*(1), 30-33.
- Gómez, R. L. (2002). Variability and detection of invariant structure. *Psychological Science, 13*(5), 431-436.
- Gonzalez-Gomez, N., & Nazzi, T. (2012a). Phonotactic acquisition in healthy preterm infants. *Developmental science, 15*(6), 885-894.
- Gonzalez-Gomez, N., & Nazzi, T. (2012b). Acquisition of nonadjacent phonological dependencies in the native language during the first year of life. *Infancy, 17*(5), 498-524.
- Gonzalez-Gomez, N., & Nazzi, T. (2013). Effects of prior phonotactic knowledge on infant word segmentation: the case of nonadjacent dependencies. *Journal of Speech, Language, and Hearing Research, 56*(3), 840-849.
- Gopnik, A., & Meltzoff, A. (1987). The development of categorization in the second year and its relation to other cognitive and linguistic developments. *Child development, 58*, 1523-1531.
- Goren, C. C., Sarty, M., & Wu, P. Y. (1975). Visual following and pattern discrimination of face-like stimuli by newborn infants. *Pediatrics, 56*(4), 544-549.
- Gottlieb, G. (1968). Prenatal behavior of birds. *The Quarterly review of biology, 43*(2), 148-174.
- Gottlieb, G. (1971). Ontogenesis of sensory function in birds and mammals. In E. Tobach, L. R. Aronson, & E. Shaw (Eds.), *The biopsychology of development* (pp. 67-128). New York: Academic Press.
- Goujon, A., & Fagot, J. (2013). Learning of spatial statistics in nonhuman primates: contextual cueing in baboons (*Papio papio*). *Behavioural Brain Research, 247*, 101-109.

- Gout, A. (2001). Etapes précoces de l'acquisition du lexique. Unpublished Dissertation, Ecole des Hautes Etudes en Sciences Sociales, Paris, France.
- Goyet, L., Millotte, S., Christophe, A., & Nazzi, T. (2016). Processing continuous speech in infancy: From major prosodic units to isolated word forms. In J. Lidz, J. Pater and W. Snyder (Eds.), *Oxford Handbook of Developmental Linguistics* (pp. 133-153). Oxford University Press.
- Goyet, L., Nishibayashi, L. L., & Nazzi, T. (2013). Early syllabic segmentation of fluent speech by infants acquiring French. *PLoS one*, *8*(11), e79646.
- Graven, S. N., & Browne, J. V. (2008). Auditory development in the fetus and infant. *Newborn and infant nursing reviews*, *8*(4), 187-193.
- Green, J. R., Moore, C. A., Higashikawa, M., & Steeve, R. W. (2000). The physiologic development of speech motor control: Lip and jaw coordination. *Journal of Speech, Language, and Hearing Research*, *43*(1), 239-255.
- Grönqvist, H., Brodd, K. S., & Rosander, K. (2011). Development of smooth pursuit eye movements in very prematurely born infants: 2. The low-risk subgroup. *Acta Paediatrica*, *100*(7).
- Grosjean, F. (1982). *Life with two languages: An introduction to bilingualism*. Harvard University Press.
- Guarini, A., & Sansavini, A. (2011). Language and literacy in preterm children. *Advances in psychology research*, *82*, 153-158.
- Guarini, A., Marini, A., Savini, S., Alessandroni, R., Faldella, G., & Sansavini, A. (2016). Linguistic features in children born very preterm at preschool age. *Developmental Medicine & Child Neurology*, *58*(9), 949-956.
- Guarini, A., Sansavini, A., Fabbri, C., Alessandroni, R., Faldella, G., & Karmiloff-Smith, A. (2009). Reconsidering the impact of preterm birth on language outcome. *Early human development*, *85*(10), 639-645.
- Guellaï, B., Coulon, M., & Streri, A. (2011). The role of motion and speech in face recognition at birth. *Visual Cognition*, *19*(9), 1212-1233.
- Hallé, P. A., & de Boysson-Bardies, B. (1994). Emergence of an early receptive lexicon: Infants' recognition of words. *Infant behavior and development*, *17*(2), 119-129.
- Hauser, M. D., Newport, E. L., & Aslin, R. N. (2001). Segmentation of the speech stream in a non-human primate: statistical learning in cotton-top tamarins. *Cognition*, *78*(3), B53-B64.

- Haynes, H., White, B. L., & Held, R. (1965). Visual accommodation in human infants. *Science*, *148*(3669), 528-530.
- Head, L. M., Baralt, M., & Mahoney, A. E. D. (2015). Bilingualism as a potential strategy to improve executive function in preterm infants: A review. *Journal of Pediatric Health Care*, *29*(2), 126-136.
- Hepper, P. G., & Shahidullah, B. S. (1994). The development of fetal hearing. *Fetal and Maternal Medicine Review*, *8*(3), 167-179.
- Herold, B., Höhle, B., Walch, E., Weber, T., & Obladen, M. (2008). Impaired word stress pattern discrimination in very-low-birthweight infants during the first 6 months of life. *Developmental Medicine & Child Neurology*, *50*(9), 678-683.
- Hickok, G., & Small, S. L. (Eds.). (2015). *Neurobiology of language*. Academic Press.
- Hochmann, J. R., Benavides-Varela, S., Nespors, M., & Mehler, J. (2011). Consonants and vowels: different roles in early language acquisition. *Developmental science*, *14*(6), 1445-1458.
- Hoff, E., Core, C., Place, S., Rumiche, R., Señor, M., & Parra, M. (2012). Dual language exposure and early bilingual development. *Journal of child language*, *39*(1), 1-27.
- Höhle, B., Bijeljic-Babic, R., Herold, B., Weissenborn, J., & Nazzi, T. (2009). Language specific prosodic preferences during the first half year of life: Evidence from German and French infants. *Infant Behavior and Development*, *32*(3), 262-274.
- Höhle, B., Pauen, S., Hesse, V., & Weissenborn, J. (2014). Discrimination of Rhythmic Pattern at 4 Months and Language Performance at 5 Years: A Longitudinal Analysis of Data From German-Learning Children. *Language Learning*, *64*(s2), 141-164.
- Höhle, B., & Weissenborn, J. (2003). German-learning infants' ability to detect unstressed closed-class elements in continuous speech. *Developmental Science*, *6*(2), 122-127.
- Hohne, E. A., & Jusczyk, P. W. (1994). Two-month-old infants' sensitivity to allophonic differences. *Attention, Perception, & Psychophysics*, *56*(6), 613-623.
- Højen, A., & Nazzi, T. (2016). Vowel bias in Danish word-learning: processing biases are language-specific. *Developmental science*, *19*(1), 41-49.
- Hollich, G., Newman, R. S., & Jusczyk, P. W. (2005). Infants' use of synchronized visual information to separate streams of speech. *Child development*, *76*(3), 598-613.

- Holst, M., Eswaran, H., Lowery, C., Murphy, P., Norton, J., & Preissl, H. (2005). Development of auditory evoked fields in human fetuses and newborns: a longitudinal MEG study. *Clinical Neurophysiology*, *116*(8), 1949-1955.
- Holzinger, K. J. (1929). The relative effect of nature and nurture influences on twin differences. *Journal of Educational Psychology*, *20*(4), 241.
- Houston, D. M., Jusczyk, P. W., Kuijpers, C., Coolen, R., & Cutler, A. (2000). Cross-language word segmentation by 9-month-olds. *Psychonomic Bulletin & Review*, *7*(3), 504-509.
- Hunnus, S., & Geuze, R. H. (2004). Developmental changes in visual scanning of dynamic faces and abstract stimuli in infants: A longitudinal study. *Infancy*, *6*(2), 231-255.
- Hunnus, S., Geuze, R. H., Zweekens, M. J., & Bos, A. F. (2008). Effects of preterm experience on the developing visual system: A longitudinal study of shifts of attention and gaze in early infancy. *Developmental neuropsychology*, *33*(4), 521-535.
- Hunter, M. A., & Ames, E. W. (1988). A multifactor model of infant preferences for novel and familiar stimuli. *Advances in infancy research*.
- Inder, T. E., Warfield, S. K., Wang, H., Hüppi, P. S., & Volpe, J. J. (2005). Abnormal cerebral structure is present at term in premature infants. *Pediatrics*, *115*(2), 286-294.
- Inder, T. E., Wells, S. J., Mogridge, N. B., Spencer, C., & Volpe, J. J. (2003). Defining the nature of the cerebral abnormalities in the premature infant: a qualitative magnetic resonance imaging study. *The Journal of pediatrics*, *143*(2), 171-179.
- Iwata, S., Nakamura, T., Hizume, E., Kihara, H., Takashima, S., Matsuishi, T., & Iwata, O. (2012). Qualitative brain MRI at term and cognitive outcomes at 9 years after very preterm birth. *Pediatrics*, peds-2011.
- Jansson-Verkasalo, E., Ruusuvirta, T., Huotilainen, M., Alku, P., Kushnerenko, E., Suominen, K., ... Hallman, M. (2010). Atypical perceptual narrowing in prematurely born infants is associated with compromised language acquisition at 2 years of age. *BMC Neuroscience*, *11*, 88.
- Jardri, R., Houfflin-Debarge, V., Delion, P., Pruvo, J. P., Thomas, P., & Pins, D. (2012). Assessing fetal response to maternal speech using a noninvasive functional brain imaging technique. *International Journal of Developmental Neuroscience*, *30*(2), 159-161.

- Jardri, R., Houfflin-Debarge, V., Delion, P., Pruvo, J. P., Thomas, P., & Pins, D. (2012). Assessing fetal response to maternal speech using a noninvasive functional brain imaging technique. *International Journal of Developmental Neuroscience*, *30*(2), 159-161.
- Johnson, E.K., & Jusczyk, P.W. (2001). Word segmentation by 8-month-olds: When speech cues count more than statistics. *Journal of Memory and Language*, *44*(4), 548-567.
- Johnson, E.K., & Tyler, M.D. (2010). Testing the limits of statistical learning for word segmentation. *Developmental Science*, *13*(2), 339-345.
- Johnson, E.K., Seidl, A., & Tyler, M.D. (2014). The edge factor in early word segmentation: utterance-level prosody enables word form extraction by 6-month-olds. *PlosOne*, *9*(1), e83546.
- Johnson, M. H., Dziurawiec, S., Ellis, H., & Morton, J. (1991). Newborns' preferential tracking of face-like stimuli and its subsequent decline. *Cognition*, *40*(1), 1-19.
- Junge, C., & Cutler, A. (2014). Early word recognition and later language skills. *Brain sciences*, *4*(4), 532-559.
- Junge, C., Kooijman, V., Hagoort, P., & Cutler, A. (2012). Rapid recognition at 10 months as a predictor of language development. *Developmental science*, *15*(4), 463-473.
- Jusczyk, P. W. (1997). *The Discovery of Spoken Language*. Cambridge: MIT Press.
- Jusczyk, P. W., & Aslin, R. N. (1995). Infants' detection of the sound patterns of words in fluent speech. *Cognitive psychology*, *29*(1), 1-23.
- Jusczyk, P. W., Friederici, A. D., Wessels, J. M., Svenkerud, V. Y., & Jusczyk, A. M. (1993). Infants' sensitivity to the sound patterns of native language words. *Journal of memory and language*, *32*(3), 402-420.
- Jusczyk, P. W., & Hohne, E. A. (1997). Infants' memory for spoken words. *Science*, *277*(5334), 1984-1986.
- Jusczyk, P. W., Hohne, E. A., & Bauman, A. (1999). Infants' sensitivity to allophonic cues for word segmentation. *Attention, Perception, & Psychophysics*, *61*(8), 1465-1476.
- Jusczyk, P. W., Houston, D. M., & Newsome, M. (1999). The beginnings of word segmentation in English-learning infants. *Cognitive psychology*, *39*(3), 159-207.
- Jusczyk, P. W., & Luce, P. A. (1994). Infants' sensitivity to phonotactic patterns in the native language. *Journal of Memory and Language*, *33*(5), 630-645.

- Kabdebon, C., Peña, M., Buiatti, M., & Dehaene-Lambertz, G. (2015). Electrophysiological evidence of statistical learning of long-distance dependencies in 8-month-old preterm and full-term infants. *Brain and language, 148*, 25-36.
- Kaganovich, N., Schumaker, J., Leonard, L. B., Gustafson, D., & Macias, D. (2014). Children with a history of SLI show reduced sensitivity to audiovisual temporal asynchrony: An ERP study. *Journal of Speech, Language, and Hearing Research, 57*(4), 1480-1502.
- Karmiloff-Smith, A. (1998). Development itself is the key to understanding developmental disorders. *Trends in cognitive sciences, 2*(10), 389-398.
- Kemler Nelson, D.G., Jusczyk, P.W., Mandel, D.R., Myers, J., Turk, A., & Gerken, L.A. (1995). The Headturn Preference Procedure for testing auditory perception. *Infant Behavior and Development, 18*, 111-116.
- Kenny, P. A., & Turkewitz, G. (1986). Effects of unusually early visual stimulation on the development of homing behavior in the rat pup. *Developmental Psychobiology, 19*(1), 57-66.
- Kern, S. (2003). Le compte-rendu parental au service de l'évaluation de la production lexicale des enfants français entre 16 et 30 mois. *Glossa, (85)*, 48-62.
- Key, A. P., Lambert, E. W., Aschner, J. L., & Maitre, N. L. (2012). Influence of gestational age and postnatal age on speech sound processing in NICU infants. *Psychophysiology, 49*(5), 720-731.
- Kinney, H. C. (2006). The near-term (late preterm) human brain and risk for periventricular leukomalacia: a review. *Semin Perinatol 30* (2), 81-88.
- Klin, A., & Jones, W. (2008). Altered face scanning and impaired recognition of biological motion in a 15-month-old infant with autism. *Developmental science, 11*(1), 40-46.
- Kooijman, V., Hagoort, P., & Cutler, A. (2005). Electrophysiological evidence for prelinguistic infants' word recognition in continuous speech. *Cognitive Brain Research, 24*(1), 109-116.
- Kooijman, V., Junge, C., Johnson, E. K., Hagoort, P., & Cutler, A. (2013). Predictive brain signals of linguistic development. *Frontiers in psychology, 4*.
- Krishnan, M. L., Dyet, L. E., Boardman, J. P., Kapellou, O., Allsop, J. M., Cowan, F., ... & Counsell, S. J. (2007). Relationship between white matter apparent diffusion coefficients in preterm infants at term-equivalent age and developmental outcome at 2 years. *Pediatrics, 120*(3), e604-e609.

- Krueger, C., & Garvan, C. (2014). Emergence and retention of learning in early fetal development. *Infant Behavior and Development*, *37*(2), 162-173.
- Kubicek, C., De Boisferon, A. H., Dupierrix, E., Løevenbruck, H., Gervain, J., & Schwarzer, G. (2013). Face-scanning behavior to silently-talking faces in 12-month-old infants: The impact of pre-exposed auditory speech. *International Journal of Behavioral Development*, *37*(2), 106-110.
- Kuhl, P. K. (1991). Human adults and human infants show a “perceptual magnet effect” for the prototypes of speech categories, monkeys do not. *Attention, Perception, & Psychophysics*, *50*(2), 93-107.
- Kuhl, P. K. (2004). Early language acquisition: cracking the speech code. *Nature Reviews. Neuroscience*, *5*(11), 831.
- Kuhl, P. K. (2007). Is speech learning ‘gated’ by the social brain?. *Developmental science*, *10*(1), 110-120.
- Kuhl, P. K., & Meltzoff, A. N. (1984). The intermodal representation of speech in infants. *Infant behavior and development*, *7*(3), 361-381.
- Kuhl, P. K., & Meltzoff, A. N. (1988). Speech as an intermodal object of perception. In *Perceptual development in infancy: The Minnesota symposia on child psychology*, *20*, 235-266.
- Kuhl, P. K., & Meltzoff, A. N. (1982). The bimodal perception of speech in infancy. *Science*, *218*, 1138-1141.
- Kuhl, P. K., Conboy, B. T., Coffey-Corina, S., Padden, D., Rivera-Gaxiola, M., & Nelson, T. (2008). Phonetic learning as a pathway to language: new data and native language magnet theory expanded (NLM-e). *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *363*(1493), 979-1000.
- Kuhl, P. K., Stevens, E., Hayashi, A., Deguchi, T., Kiritani, S., & Iverson, P. (2006). Infants show a facilitation effect for native language phonetic perception between 6 and 12 months. *Developmental science*, *9*(2).
- Kuhl, P. K., Tsao, F. M., & Liu, H. M. (2003). Foreign-language experience in infancy: Effects of short-term exposure and social interaction on phonetic learning. *Proceedings of the National Academy of Sciences*, *100*(15), 9096-9101.
- Kuhl, P. K., Williams, K. A., Lacerda, F., Stevens, K. N., & Lindblom, B. (1992). Linguistic experience alters phonetic perception in infants by 6 months of age. *Science*, *257*, 606-608.

- Kuhn, P., Zores, C., Pebayle, T., Hoeft, A., Langlet, C., Escande, B., ... & Dufour, A. (2012). Infants born very preterm react to variations of the acoustic environment in their incubator from a minimum signal-to-noise ratio threshold of 5 to 10 dBA. *Pediatr Res*, *71*(4 Pt 1), 386-92.
- Kuijpers, C. T., Coolen, R., Houston, D., & Cutler, A. (1998). Using the head-turning technique to explore cross-linguistic performance differences. C. Rovee-Collier; L. Lipsitt; H. Hayne (eds.), *Advances in Infancy Research*, *12*, 205-220.
- Kushnerenko, E., Tomalski, P., Ballieux, H., Potton, A., Birtles, D., Frostick, C., & Moore, D. G. (2013). Brain responses and looking behavior during audiovisual speech integration in infants predict auditory speech comprehension in the second year of life. *Frontiers in psychology*, *4*.
- Lahav, A., & Skoe, E. (2014). An acoustic gap between the NICU and womb: a potential risk for compromised neuroplasticity of the auditory system in preterm infants. *Frontiers in neuroscience*, *8*.
- Lany, J., & Saffran, J. R. (2010). From statistics to meaning: Infants' acquisition of lexical categories. *Psychological Science*, *21*(2), 284-291.
- Larroque, B., Ancel, P. Y., Marret, S., Marchand, L., André, M., Arnaud, C., ... & Burguet, A. (2008). Neurodevelopmental disabilities and special care of 5-year-old children born before 33 weeks of gestation (the EPIPAGE study): a longitudinal cohort study. *The Lancet*, *371*(9615), 813-820.
- Lebel, C., Rasmussen, C., Wyper, K., Walker, L., Andrew, G., Yager, J., & Beaulieu, C. (2008). Brain diffusion abnormalities in children with fetal alcohol spectrum disorder. *Alcoholism: Clinical and Experimental Research*, *32*(10), 1732-1740.
- Lecanuet J. P., Grannier-Deferre C., & Busnel M.C. (1995). Human fetal auditory perception. In *Fetal Development: A Psychological Perspective*, Lecanuet J-P, Fifer WP, Krasnegor NA, Smotherman WP (eds). Lawrence Erlbaum: Hillsdale, NJ; 239-262.
- Lecanuet, J. P., & Schaal, B. (1996). Fetal sensory competencies. *European Journal of Obstetrics & Gynecology and Reproductive Biology*, *68*, 1-23.
- Lee, E. S., Yeatman, J. D., Luna, B., & Feldman, H. M. (2011). Specific language and reading skills in school-aged children and adolescents are associated with prematurity after controlling for IQ. *Neuropsychologia*, *49*(5), 906-913.
- Lemola, S., Oser, N., Urfer-Maurer, N., Brand, S., Holsboer-Trachsler, E., Bechtel, N., ... & Datta, A. N. (2017). Effects of gestational age on brain volume and cognitive

- functions in generally healthy very preterm born children during school-age: A voxel-based morphometry study. *PLoS One*, *12*(8), e0183519.
- Letourneau, S. M., & Mitchell, T. V. (2011). Gaze patterns during identity and emotion judgments in hearing adults and deaf users of American Sign Language. *Perception*, *40*(5), 563-575.
- Lewkowicz, D. J., & Hansen-Tift, A. M. (2012). Infants deploy selective attention to the mouth of a talking face when learning speech. *Proceedings of the National Academy of Sciences*, *109*(5), 1431-1436.
- Lickliter, R. (1990). Premature visual experience facilitates visual responsiveness in bobwhite quail neonates. *Infant Behavior and Development*, *13*(4), 487-496.
- Lickliter, R. (2000). The role of sensory stimulation in perinatal development: insights from comparative research for care of the high-risk infant. *Journal of Developmental & Behavioral Pediatrics*, *21*(6), 437-447.
- Lisker, L., & Abramson, A. S. (1967). Some effects of context on voice onset time in English stops. *Language and speech*, *10*(1), 1-28.
- Liu, S., Xiao, W. S., Xiao, N. G., Quinn, P. C., Zhang, Y., Chen, H., ... & Lee, K. (2015). Development of visual preference for own-versus other-race faces in infancy. *Developmental psychology*, *51*(4), 500.
- Loe, I. M., & Feldman, H. M. (2016). The Effect of Bilingual Exposure on Executive Function Skills in Preterm and Full-Term Preschoolers. *Journal of Developmental & Behavioral Pediatrics*, *37*(7), 548-556.
- Loi, E. C., Marchman, V. A., Fernald, A., & Feldman, H. M. (2017). Using Eye Movements to Assess Language Comprehension in Toddlers Born Preterm and Full Term. *The Journal of pediatrics*, *180*, 124-129.
- Luciana, M. (2003). Cognitive development in children born preterm: implications for theories of brain plasticity following early injury. *Development and psychopathology*, *15*(4), 1017-1047.
- Maddieson, I., & Disner, S. F. (1984). *Patterns of sounds*. Cambridge university press.
- Magill-Evans, J., Harrison, M. J., & Burke, S. O. (1999). Parent-child interactions and development of toddlers born preterm. *Western Journal of Nursing Research*, *21*(3), 292-312.
- Mahmoudzadeh, M., Dehaene-Lambertz, G., Fournier, M., Kongolo, G., Goudjil, S., Dubois, J., ... & Wallois, F. (2013). Syllabic discrimination in premature human infants prior

- to complete formation of cortical layers. *Proceedings of the National Academy of Sciences*, *110*(12), 4846-4851.
- Mandel, D. R., Jusczyk, P. W., & Pisoni, D. B. (1995). Infants' recognition of the sound patterns of their own names. *Psychological Science*, *6*(5), 314-317.
- Månsson, J., & Stjernqvist, K. (2014). Children born extremely preterm show significant lower cognitive, language and motor function levels compared with children born at term, as measured by the Bayley-III at 2.5 years. *Acta paediatrica*, *103*(5), 504-511.
- Marchman, V. A., Adams, K. A., Loi, E. C., Fernald, A., & Feldman, H. M. (2016). Early language processing efficiency predicts later receptive vocabulary outcomes in children born preterm. *Child Neuropsychology*, *22*(6), 649-665.
- Mattys, S. L., & Jusczyk, P. W. (2001). Phonotactic cues for segmentation of fluent speech by infants. *Cognition*, *78*(2), 91-121.
- Mattys, S. L., Jusczyk, P. W., Luce, P. A., & Morgan, J. L. (1999). Phonotactic and prosodic effects on word segmentation in infants. *Cognitive psychology*, *38*(4), 465-494.
- Maurer, D., Lewis, T. L., Brent, H. P., & Levin, A. V. (1999). Rapid improvement in the acuity of infants after visual input. *Science*, *286*(5437), 108-110.
- Maye, J., Werker, J. F., & Gerken, L. (2002). Infant sensitivity to distributional information can affect phonetic discrimination. *Cognition*, *82*(3), B101-B111.
- Mayor, J., & Plunkett, K. (2010, January). Vocabulary Spurt; Are Infants full of Zipf?. In *Proceedings of the Cognitive Science Society*, *32*(32).
- McCullough, S., & Emmorey, K. (1997). Face processing by deaf ASL signers: evidence for expertise in distinguishing local features. *Journal of Deaf Studies and Deaf Education*, *2*(2), 212-222.
- McGowan, J. E., Alderdice, F. A., Holmes, V. A., & Johnston, L. (2011). Early childhood development of late-preterm infants: a systematic review. *Pediatrics*, *ped*s-2010.
- Mechelli, A., Crinion, J. T., Noppeney, U., O'doherty, J., Ashburner, J., Frackowiak, R. S., & Price, C. J. (2004). Neurolinguistics: structural plasticity in the bilingual brain. *Nature*, *431*(7010), 757-757.
- Mehler, J., & Christophe, A. (1994). Language in the infant's mind. *Philosophical Transactions: Biological Sciences*, *13*-20.
- Mehler, J., Jusczyk, P., Lambertz, G., Halsted, N., Bertoncini, J., & Amiel-Tison, C. (1988). A precursor of language acquisition in young infants. *Cognition*, *29*(2), 143-178.

- Mersad, K., & Nazzi, T. (2012). When Mommy comes to the rescue of statistics: Infants combine top-down and bottom-up cues to segment speech. *Language Learning and Development, 8*(3), 303-315.
- Miyawaki, K., Jenkins, J. J., Strange, W., Liberman, A. M., Verbrugge, R., & Fujimura, O. (1975). An effect of linguistic experience: The discrimination of [r] and [l] by native speakers of Japanese and English. *Perception & Psychophysics, 18*(5), 331-340.
- Mohades, S. G., Struys, E., Van Schuerbeek, P., Mondt, K., Van De Craen, P., & Luybaert, R. (2012). DTI reveals structural differences in white matter tracts between bilingual and monolingual children. *Brain Research, 1435*, 72-80.
- Moon, C. (2011). The role of early auditory development in attachment and communication. *Clinics in perinatology, 38*(4), 657-669.
- Moon, C., Panneton-Cooper, R. P., & Fifer, W. P. (1993). Two-day-olds prefer their native language. *Infant behavior and development, 16*(4), 495-500.
- Moore, J. K. (2002). Maturation of human auditory cortex: implications for speech perception. *Annals of Otology, Rhinology & Laryngology, 111*(5_suppl), 7-10.
- Moossavi, A., & Panahi, R. (2017). A review of the effects of preterm birth on neural development, language acquisition and auditory system. *Auditory and Vestibular Research, 26*(3).
- Morales, M., Mundy, P., & Rojas, J. (1998). Following the direction of gaze and language development in 6-month-olds. *Infant Behavior and Development, 21*(2), 373-377.
- Morales, M., Mundy, P., Delgado, C. E., Yale, M., Messinger, D., Neal, R., & Schwartz, H. K. (2000). Responding to joint attention across the 6-through 24-month age period and early language acquisition. *Journal of applied developmental psychology, 21*(3), 283-298.
- Morgan, J. L., & Demuth, K. (1996). Signal to Syntax: an overview. In J.L. Morgan & K. Demuth (Eds.), *Signal to syntax: Bootstrapping from speech to grammar in early acquisition* (pp. 1- 22). Mahwah, NJ: Lawrence Erlbaum Associates.
- Morton, J., & Johnson, M. H. (1991). CONSPEC and CONLERN: a two-process theory of infant face recognition. *Psychological review, 98*(2), 164.
- Mulder, H., Pitchford, N. J., & Marlow, N. (2010). Processing speed and working memory underlie academic attainment in very preterm children. *Archives of Disease in Childhood-Fetal and Neonatal Edition, 95*(4), F267-F272.

- Munakata, S., Okada, T., Okahashi, A., Yoshikawa, K., Usukura, Y., Makimoto, M., ... & Okuhata, Y. (2013). Gray matter volumetric MRI differences late-preterm and term infants. *Brain and Development, 35*(1), 10-16.
- Myers, E. H., Hampson, M., Vohr, B., Lacadie, C., Frost, S. J., Pugh, K. R., ... & Ment, L. R. (2010). Functional connectivity to a right hemisphere language center in prematurely born adolescents. *Neuroimage, 51*(4), 1445-1452.
- Nagy, E. (2008). Innate intersubjectivity: Newborns' sensitivity to communication disturbance. *Developmental Psychology, 44*(6), 1779.
- Nazzi, T. (2005). Use of phonetic specificity during the acquisition of new words: Differences between consonants and vowels. *Cognition, 98*(1), 13-30.
- Nazzi, T., & Bertoncini, J. (2003). Before and after the vocabulary spurt: two modes of word acquisition?. *Developmental Science, 6*(2), 136-142.
- Nazzi, T., Bertoncini, J., & Bijeljac-Babic, R. (2009). A perceptual equivalent of the labial-coronal effect in the first year of life. *The Journal of the Acoustical Society of America, 126*(3), 1440-1446.
- Nazzi, T., Bertoncini, J., & Mehler, J. (1998). Language discrimination by newborns: toward an understanding of the role of rhythm. *Journal of Experimental Psychology: Human perception and performance, 24*(3), 756.
- Nazzi, T., Iakimova, G., Bertoncini, J., Frédonie, S., & Alcantara, C. (2006). Early segmentation of fluent speech by infants acquiring French: Emerging evidence for crosslinguistic differences. *Journal of Memory and Language, 54*(3), 283-299.
- Nazzi, T., Jusczyk, P. W., & Johnson, E. K. (2000). Language discrimination by English-learning 5-month-olds: Effects of rhythm and familiarity. *Journal of Memory and Language, 43*(1), 1-19.
- Nazzi, T., Mersad, K., Sundara, M., Iakimova, G., & Polka, L. (2014). Early word segmentation in infants acquiring Parisian French: task-dependent and dialect-specific aspects. *Journal of Child Language, 41*(3), 600-633.
- Nazzi, T., Poltrock, S., & Von Holzen, K. (2016). The developmental origins of the consonant bias in lexical processing. *Current Directions in Psychological Science, 25*(4), 291-296.
- Nelson, C. A. (2014). Romania's abandoned children. Harvard University Press.
- Nelson, C. A., Bos, K., Gunnar, M. R., & Sonuga-Barke, E. J. (2011). V. The neurobiological toll of early human deprivation. *Monographs of the Society for Research in Child Development, 76*(4), 127-146.

- Nespor, M., Peña, M., & Mehler, J. (2003). On the different roles of vowels and consonants in speech processing and language acquisition. *Lingue e linguaggio, 2*(2), 203-230.
- New, B., Araújo, V., & Nazzi, T. (2008). Differential processing of consonants and vowels in lexical access through reading. *Psychological Science, 19*(12), 1223-1227.
- New, B., Pallier, C., Brysbaert, M., & Ferrand, L. (2004). Lexique 2: A new French lexical database. *Behavior Research Methods, Instruments, & Computers, 36*(3), 516-524.
- Newman, R., Ratner, N. B., Jusczyk, A. M., Jusczyk, P. W., & Dow, K. A. (2006). Infants' early ability to segment the conversational speech signal predicts later language development: a retrospective analysis. *Developmental psychology, 42*(4), 643.
- Ngon, C., Martin, A., Dupoux, E., Cabrol, D., Dutat, M., & Peperkamp, S. (2013). (Non) words,(non) words,(non) words: evidence for a protolexicon during the first year of life. *Developmental Science, 16*(1), 24-34.
- Nishibayashi, L. L., & Nazzi, T. (2016). Vowels, then consonants: Early bias switch in recognizing segmented word forms. *Cognition, 155*, 188-203.
- Nishibayashi, L. L., Goyet, L., & Nazzi, T. (2015). Early speech segmentation in French-learning infants: Monosyllabic words versus embedded syllables. *Language and speech, 58*(3), 334-350.
- Ortiz-Mantilla, S., Choudhury, N., Leevers, H., & Benasich, A. A. (2008). Understanding language and cognitive deficits in very low birth weight children. *Developmental psychobiology, 50*(2), 107-126.
- Ozturk, O., Krehm, M., & Vouloumanos, A. (2013). Sound symbolism in infancy: evidence for sound-shape cross-modal correspondences in 4-month-olds. *Journal of Experimental Child Psychology, 114*(2), 173-186.
- Palisano, R. J. (1986). Use of chronological and adjusted ages to compare motor development of healthy preterm and fullterm infants. *Developmental Medicine & Child Neurology, 28*(2), 180-187.
- Papile, L. A., Burstein, J., Burstein, R., & Koffler, H. (1978). Incidence and evolution of subependymal and intraventricular hemorrhage: a study of infants with birth weights less than 1,500 gm. *The Journal of pediatrics, 92*(4), 529-534.
- Parise, E., & Csibra, G. (2012). Electrophysiological evidence for the understanding of maternal speech by 9-month-old infants. *Psychological Science, 23*(7), 728-733.

- Pascalis, O., de Schonen, S., Morton, J., Deruelle, C., & Fabre-Grenet, M. (1995). Mother's face recognition by neonates: A replication and an extension. *Infant Behavior and Development, 18*(1), 79-85.
- Patterson, M. L., & Werker, J. F. (1999). Matching phonetic information in lips and voice is robust in 4.5-month-old infants. *Infant Behavior and Development, 22*(2), 237-247.
- Patterson, M. L., & Werker, J. F. (2002). Infants' ability to match dynamic phonetic and gender information in the face and voice. *Journal of experimental child psychology, 81*(1), 93-115.
- Peña, M., Arias, D., & Dehaene-Lambertz, G. (2014). Gaze following is accelerated in healthy preterm infants. *Psychological science, 25*(10), 1884-1892.
- Peña, M., Maki, A., Kováčič, D., Dehaene-Lambertz, G., Koizumi, H., Bouquet, F., & Mehler, J. (2003). Sounds and silence: an optical topography study of language recognition at birth. *Proceedings of the National Academy of Sciences, 100*(20), 11702-11705.
- Peña, M., Pittaluga, E., & Mehler, J. (2010). Language acquisition in premature and full-term infants. *Proceedings of the National Academy of Sciences, 107*(8), 3823-3828.
- Peña, M., Werker, J. F., & Dehaene-Lambertz, G. (2012). Earlier speech exposure does not accelerate speech acquisition. *Journal of Neuroscience, 32*(33), 11159-11163.
- Perea, M., & Lupker, S. J. (2004). Can CANISO activate CASINO? Transposed-letter similarity effects with nonadjacent letter positions. *Journal of memory and language, 51*(2), 231-246.
- Pérez-Pereira, M., Fernández, P., Gómez-Taibo, M. L., & Resches, M. (2014). Language development of low risk preterm infants up to the age of 30months. *Early human development, 90*(10), 649-656.
- Perszyk, D. R., Ferguson, B., & Waxman, S. R. (2016). Maturation constrains the effect of exposure in linking language and thought: evidence from healthy preterm infants. *Developmental science, 1-9*
- Peterson, B. S., Vohr, B., Kane, M. J., Whalen, D. H., Schneider, K. C., Katz, K. H., ... & Ment, L. R. (2002). A functional magnetic resonance imaging study of language processing and its cognitive correlates in prematurely born children. *Pediatrics, 110*(6), 1153-1162.

- Piaget, J. (1961). The genetic approach to the psychology of thought. *Understanding Children, 52*, 35-40.
- Piaget, J. (1970). *Science of education and the psychology of the child*. New York: Orion Press.
- Pickens, J., Field, T., Nawrocki, T., Martinez, A., Soutullo, D., & Gonzalez, J. (1994). Full-term and preterm infants' perception of face-voice synchrony. *Infant Behavior and Development, 17*(4), 447-455.
- Pierrat, V., Marchand-Martin, L., Arnaud, C., Kaminski, M., Resche-Rigon, M., Lebeaux, C., ... & Ancel, P. Y. (2017). Neurodevelopmental outcome at 2 years for preterm children born at 22 to 34 weeks' gestation in France in 2011: EPIPAGE-2 cohort study. *Bmj, 358*, j3448.
- Polka, L., & Sundara, M. (2012). Word segmentation in monolingual infants acquiring Canadian English and Canadian French: Native language, cross-dialect, and cross-language comparisons. *Infancy, 17*(2), 198-232.
- Polka, L., & Werker, J. F. (1994). Developmental changes in perception of nonnative vowel contrasts. *Journal of Experimental Psychology: Human perception and performance, 20*(2), 421.
- Polka, L., Orena, A. J., Sundara, M., & Worrall, J. (2017). Segmenting words from fluent speech during infancy—challenges and opportunities in a bilingual context. *Developmental science, 20*(1).
- Poltrock, S., & Nazzi, T. (2015). Consonant/vowel asymmetry in early word form recognition. *Journal of experimental child psychology, 131*, 135-148.
- Pons, F., Andreu, L., Sanz-Torrent, M., Buil-Legaz, L., & Lewkowicz, D. J. (2013). Perception of audio-visual speech synchrony in Spanish-speaking children with and without specific language impairment. *Journal of child language, 40*(3), 687-700.
- Pons, F., Bosch, L., & Lewkowicz, D. J. (2015). Bilingualism modulates infants' selective attention to the mouth of a talking face. *Psychological science, 26*(4), 490-498.
- Pons, F., Lewkowicz, D. J., Soto-Faraco, S., & Sebastián-Gallés, N. (2009). Narrowing of intersensory speech perception in infancy. *Proceedings of the National Academy of Sciences, 106*(26), 10598-10602.
- Pritchard, V. E., Clark, C. A., Liberty, K., Champion, P. R., Wilson, K., & Woodward, L. J. (2009). Early school-based learning difficulties in children born very preterm. *Early human development, 85*(4), 215-224.

- Pritchard, V.E., Bora, S., Austin, N.C., Levin, K.J., & Woodward, L.J. (2014). Identifying very preterm children at educational risk using a school readiness framework. *Pediatrics, 134*(3), e825-832.
- Pulvermüller, F., & Fadiga, L. (2010). Active perception: sensorimotor circuits as a cortical basis for language. *Nature reviews. Neuroscience, 11*(5), 351.
- Putnick, D. L., Bornstein, M. H., Eryigit-Madzwamuse, S., & Wolke, D. (2017). Long-term stability of language performance in very preterm, moderate-late preterm, and term children. *The Journal of pediatrics, 181*, 74-79.
- Querleu, D., Renard, X., Versyp, F., Paris-Delrue, L., & Crèpin, G. (1988). Fetal hearing. *European Journal of Obstetrics & Gynecology and Reproductive Biology, 28*(3), 191-212.
- Quigley, M. A., Poulsen, G., Boyle, E., Wolke, D., Field, D., Alfirevic, Z., & Kurinczuk, J. J. (2012). Early term and late preterm birth are associated with poorer school performance at age 5 years: a cohort study. *Archives of Disease in Childhood-Fetal and Neonatal Edition, 97*(3), F167-F173.
- Ragó, A., Honbolygó, F., Róna, Z., Beke, A., & Csépe, V. (2014). Effect of maturation on suprasegmental speech processing in full-and preterm infants: a mismatch negativity study. *Research in developmental disabilities, 35*(1), 192-202.
- Ramon-Casas, M., Bosch, L., Iriando, M., & Krauel, X. (2013). Word recognition and phonological representation in very low birth weight preterms. *Early human development, 89*(1), 55-63.
- Ramus, F., Hauser, M. D., Miller, C., Morris, D., & Mehler, J. (2000). Language discrimination by human newborns and by cotton-top tamarin monkeys. *Science, 288*(5464), 349-351.
- Ramus, F., Nespors, M., & Mehler, J. (1999). Correlates of linguistic rhythm in the speech signal. *Cognition, 73*(3), 265-292.
- Rand, K., & Lahav, A. (2014). Impact of the NICU environment on language deprivation in preterm infants. *Acta Paediatrica, 103*(3), 243-248.
- Reidy, N., Morgan, A., Thompson, D. K., Inder, T. E., Doyle, L. W., & Anderson, P. J. (2013). Impaired language abilities and white matter abnormalities in children born very preterm and/or very low birth weight. *The Journal of pediatrics, 162*(4), 719-724.
- Reisberg, D., McLean, J., & Goldfield, A. (1987). Easy to hear but hard to understand: a lip-reading advantage with intact auditory stimuli. In B. Dodd & R. Campbell (Eds.),

- Hearing by eye: the psychology of lip-reading (pp. 97–114). Hillsdale, NJ: Lawrence Erlbaum Associates
- Ricci, D., Cesarini, L., Romeo, D. M., Gallini, F., Serrao, F., Groppo, M., ... & Ratiglia, R. (2008). Visual function at 35 and 40 weeks' postmenstrual age in low-risk preterm infants. *Pediatrics*, *122*(6), e1193-e1198.
- Rivera-Gaxiola, M., Silva-Pereyra, J., & Kuhl, P. K. (2005). Brain potentials to native and non-native speech contrasts in 7-and 11-month-old American infants. *Developmental science*, *8*(2), 162-172.
- Romeo, D. M., Di Stefano, A., Conversano, M., Ricci, D., Mazzone, D., Romeo, M. G., & Mercuri, E. (2010). Neurodevelopmental outcome at 12 and 18 months in late preterm infants. *European journal of paediatric neurology*, *14*(6), 503-507.
- Romero, R., Hassan, S. S., Gajer, P., Tarca, A. L., Fadrosh, D. W., Bieda, J., ... & Ravel, J. (2014). The vaginal microbiota of pregnant women who subsequently have spontaneous preterm labor and delivery and those with a normal delivery at term. *Microbiome*, *2*(1), 18.
- Rose, S. A., Jankowski, J. J., & Feldman, J. F. (2008). The inversion effect in infancy: The role of internal and external features. *Infant Behavior and Development*, *31*(3), 470-480.
- Ross, G. (1985). Use of the Bayley Scales to characterize abilities of premature infants. *Child Development*, 835-842.
- Saavalainen, P., Luoma, L., Bowler, D., Timonen, T., Määttä, S., Laukkanen, E., & Herrgård, E. (2006). Naming skills of children born preterm in comparison with their term peers at the ages of 9 and 16 years. *Developmental Medicine & Child Neurology*, *48*(1), 28-32.
- Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996). Statistical learning by 8-month-old infants. *Science*, 1926-1928.
- Saffran, J. R., Johnson, E. K., Aslin, R. N., & Newport, E. L. (1999). Statistical learning of tone sequences by human infants and adults. *Cognition*, *70*(1), 27-52.
- Saffran, J.R., Newport, E.L., & Aslin, R.N. (1996). Word segmentation: The role of distributional cues. *Journal of Memory and Language*, *35*(4), 606-621.
- Sansavini, A., Bertoncini, J., & Giovanelli, G. (1997). Newborns discriminate the rhythm of multisyllabic stressed words. *Developmental Psychology*, *33*(1), 3.

- Sansavini, A., Guarini, A., & Caselli, M. C. (2011). Preterm birth: Neuropsychological profiles and atypical developmental pathways. *Developmental disabilities research reviews, 17*(2), 102-113.
- Sansavini, A., Guarini, A., Alessandrini, R., Faldella, G., Giovanelli, G., & Salvioli, G. (2006). Early relations between lexical and grammatical development in very immature Italian preterms. *Journal of Child Language, 33*(1), 199-216.
- Sansavini, A., Guarini, A., Savini, S., Broccoli, S., Justice, L., Alessandrini, R., & Faldella, G. (2011). Longitudinal trajectories of gestural and linguistic abilities in very preterm infants in the second year of life. *Neuropsychologia, 49*(13), 3677-3688.
- Scheele, A. F., Leseman, P. P., & Mayo, A. Y. (2010). The home language environment of monolingual and bilingual children and their language proficiency. *Applied Psycholinguistics, 31*(1), 117-140.
- Schults, A., Tulviste, T., & Haan, E. (2013). Early vocabulary in full term and preterm Estonian children. *Early human development, 89*(9), 721-726.
- Sebastián-Gallés, N., & Bosch, L. (2002). Building phonotactic knowledge in bilinguals: role of early exposure. *Journal of Experimental Psychology: Human Perception and Performance, 28*(4), 974.
- Seidl, A., Tincoff, R., Baker, C., & Cristia, A. (2015). Why the body comes first: effects of experimenter touch on infants' word finding. *Developmental science, 18*(1), 155-164.
- Shankar, S., Evans, M. A., & Bobier, W. R. (2007). Hyperopia and emergent literacy of young children: pilot study. *Optometry & Vision Science, 84*(11), 1031-1038.
- Shaw, K. E., & Bortfeld, H. (2015). Sources of confusion in infant audiovisual speech perception research. *Frontiers in psychology, 6*.
- Shi, R., Werker, J. F., & Morgan, J. L. (1999). Newborn infants' sensitivity to perceptual cues to lexical and grammatical words. *Cognition, 72*(2), B11-B21.
- Shi, L., Zhou, Y., Ou, J., Gong, J., Wang, S., Cui, X., ... & Luo, X. (2015). Different visual preference patterns in response to simple and complex dynamic social stimuli in preschool-aged children with autism spectrum disorders. *PLoS one, 10*(3), e0122280.
- Shukla, M., White, K. S., & Aslin, R. N. (2011). Prosody guides the rapid mapping of auditory word forms onto visual objects in 6-month-old infants. *Proceedings of the National Academy of Sciences, 108*(15), 6038-6043.
- Skinner, B. F. (1957). *Verbal behavior*. New York: Appleton-Century-Crofts.

- Skoruppa, K., Pons, F., Christophe, A., Bosch, L., Dupoux, E., Sebastián-Gallés, N., ... & Peperkamp, S. (2009). Language-specific stress perception by 9-month-old French and Spanish infants. *Developmental Science, 12*(6), 914-919.
- Sokol, S. (1978). Measurement of infant visual acuity from pattern reversal evoked potentials. *Vision Research, 18*(1), 33-39.
- Sommerfelt, K., Markestad, T., & Ellertsen, B. (1998). Neuropsychological performance in low birth weight preschoolers: a population-based, controlled study. *European journal of pediatrics, 157*(1), 53-58.
- Soria-Pastor, S., Padilla, N., Zubiaurre-Elorza, L., Ibarretxe-Bilbao, N., Botet, F., Costas-Moragas, C., ... & Junque, C. (2009). Decreased regional brain volume and cognitive impairment in preterm children at low risk. *Pediatrics, 124*(6), e1161-e1170.
- Spelke, E., & Cortelou, A. (1980). Perceptual aspects of social knowing In *Infant Social Cognition* ed. ME Lamb & LR Sherrod.
- Spierer, A., Royzman, Z., & Kuint, J. (2004). Visual acuity in premature infants. *Ophthalmologica, 218*(6), 397-401.
- Stene-Larsen, K., Brandlistuen, R. E., Lang, A. M., Landolt, M. A., Latal, B., & Vollrath, M. E. (2014). Communication impairments in early term and late preterm children: a prospective cohort study following children to age 36 months. *The Journal of pediatrics, 165*(6), 1123-1128.
- Stevens, K. N., & Blumstein, S. E. (1978). Invariant cues for place of articulation in stop consonants. *The Journal of the Acoustical Society of America, 64*(5), 1358-1368.
- Stevens, K. N., & Blumstein, S. E. (1981). The search for invariant acoustic correlates of phonetic features. *Perspectives on the study of speech, 1*-38.
- Stolt, S., Haataja, L., Lapinleimu, H., & Lehtonen, L. (2009). The early lexical development and its predictive value to language skills at 2 years in very-low-birth-weight children. *Journal of Communication Disorders, 42*(2), 107-123.
- Stolt, S., Klippi, A., Launonen, K., Munck, P., Lehtonen, L., Lapinleimu, H., & Haataja, L. (2007). Size and composition of the lexicon in prematurely born very-low-birth-weight and full-term Finnish children at two years of age. *Journal of child language, 34*(2), 283-310.
- Streri, A., Coulon, M., Marie, J., & Yeung, H. H. (2016). Developmental Change in Infants' Detection of Visual Faces that Match Auditory Vowels. *Infancy, 21*(2), 177-198.

- Summerfield, Q. (1992). Lipreading and audio-visual speech perception. *Philosophical Transactions: Biological Sciences*, 71-78.
- Swingle, D. (2005). 11-month-olds' knowledge of how familiar words sound. *Developmental science*, 8(5), 432-443.
- Telford, E. J., Fletcher-Watson, S., Gillespie-Smith, K., Pataky, R., Sparrow, S., Murray, I. C., ... & Boardman, J. P. (2016). Preterm birth is associated with atypical social orienting in infancy detected using eye tracking. *Journal of Child Psychology and Psychiatry*, 57(7), 861-868.
- Tenenbaum, E. J., Shah, R. J., Sobel, D. M., Malle, B. F., & Morgan, J. L. (2013). Increased Focus on the Mouth Among Infants in the First Year of Life: A Longitudinal Eye-Tracking Study. *Infancy*, 18(4), 534-553.
- The World Atlas of Language Structures. Website accessed 27/09/2017: <http://wals.info/chapter/3>
- Therien, J. M., Worwa, C. T., & Mattia, F. R. (2004). Altered pathways for auditory discrimination and recognition memory in preterm infants. *Developmental medicine and child neurology*, 46(12), 816-824.
- Thompson, D. K., Inder, T. E., Faggian, N., Johnston, L., Warfield, S. K., Anderson, P. J., ... & Egan, G. F. (2011). Characterization of the corpus callosum in very preterm and full-term infants utilizing MRI. *Neuroimage*, 55(2), 479-490.
- Tincoff, R., & Jusczyk, P. W. (1999). Some beginnings of word comprehension in 6-month-olds. *Psychological Science*, 10(2), 172-175.
- Tincoff, R., & Jusczyk, P. W. (2012). Six-Month-Olds comprehend words that refer to parts of the body. *Infancy*, 17(4), 432-444.
- Tomalski, P., Ribeiro, H., Ballieux, H., Axelsson, E. L., Murphy, E., Moore, D. G., & Kushnerenko, E. (2013). Exploring early developmental changes in face scanning patterns during the perception of audiovisual mismatch of speech cues. *European Journal of Developmental Psychology*, 10(5), 611-624.
- Tomasello, M. (1995). Joint attention as social cognition. *Joint attention: Its origins and role in development*, 103-130.
- Toro, J. M., & Trobalón, J. B. (2005). Statistical computations over a speech stream in a rodent. *Attention, Perception, & Psychophysics*, 67(5), 867-875.
- Tullberg, M., Fletcher, E., DeCarli, C., Mungas, D., Reed, B. R., Harvey, D. J., ... & Jagust, W. J. (2004). White matter lesions impair frontal lobe function regardless of their location. *Neurology*, 63(2), 246-253.

- Turkewitz, G., & Kenny, P. A. (1982). Limitations on input as a basis for neural organization and perceptual development: A preliminary theoretical statement. *Developmental psychobiology*, *15*(4), 357-368.
- Turkewitz, G., & Kenny, P. A. (1985). The role of developmental limitations of sensory input on sensory/perceptual organization. *Journal of Developmental & Behavioral Pediatrics*, *6*(5), 302-306.
- Van Noort-Van Der Spek, I. L., Franken, M. C., & Weisglas-Kuperus, N. (2011). Language functions in preterm children: A systematic review and meta-analysis. *Pediatric Research*, *70*, 357-357.
- Vatikiotis-Bateson, E., Eigsti, I. M., Yano, S., & Munhall, K. G. (1998). Eye movement of perceivers during audiovisual speech perception. *Attention, Perception, & Psychophysics*, *60*(6), 926-940.
- Veldhuizen, E. J., & Haagsman, H. P. (2000). Role of pulmonary surfactant components in surface film formation and dynamics. *Biochimica et Biophysica Acta (BBA)- Biomembranes*, *1467*(2), 255-270.
- Vihman, M. M., Nakai, S., DePaolis, R. A., & Hallé, P. (2004). The role of accentual pattern in early lexical representation. *Journal of Memory and Language*, *50*(3), 336-353.
- Vohr, B. R. (2014). Neurodevelopmental outcomes of extremely preterm infants. *Clinics in Perinatology*, *41*(1), 241-255.
- Vohr, B. R. (2016). Language and hearing outcomes of preterm infants. In *Seminars in perinatology*, *40*(8), 510-519. WB Saunders.
- Volpe, J.J., (1991). Cognitive deficits in premature infants. *New England Journal of Medicine* *325* (4), 276-278.
- Volpe, J. J. (2009). Brain injury in premature infants: a complex amalgam of destructive and developmental disturbances. *The Lancet Neurology*, *8*(1), 110-124.
- Wachman, E. M., & Lahav, A. (2011). The effects of noise on preterm infants in the NICU. *Archives of Disease in Childhood-Fetal and Neonatal Edition*, *96*(4), F305-F309.
- Walch, E., Chaudhary, T., Herold, B., & Obladen, M. (2009). Parental bilingualism is associated with slower cognitive development in very low birth weight infants. *Early Human Development*, *85*(7), 449-454.
- Walker, A. S. (1982). Intermodal perception of expressive behaviors by human infants. *Journal of Experimental Child Psychology*, *33*(3), 514-535.

- Waxman, S. R. (2003). Links between object categorization and naming. Early category and concept development: Making sense of the blooming, buzzing confusion, 213-241.
- Weber, C., Hahne, A., Friedrich, M., & Friederici, A. D. (2004). Discrimination of word stress in early infant perception: Electrophysiological evidence. *Cognitive Brain Research*, *18*(2), 149-161.
- Institut National de la Santé et de la Recherche Médicale. Website accessed 25/09/2017. <https://www.inserm.fr/thematiques/biologie-cellulaire-developpement-et-evolution/dossiers-d-information/la-prematurite-un-monde-a-explorer>
- Weikum, W. M., Vouloumanos, A., Navarra, J., Soto-Faraco, S., Sebastian-Galles, N., & Werker, J. F. (2007). Visual language discrimination in infancy. *Science*, *316*, 1159.
- Werker, J. (2012). Perceptual foundations of bilingual acquisition in infancy. *Annals of the New York Academy of Sciences*, *1251*(1), 50-61.
- Werker, J. F., & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant behavior and development*, *7*(1), 49-63.
- Werker, J. F., & Tees, R. C. (2005). Speech perception as a window for understanding plasticity and commitment in language systems of the brain. *Developmental psychobiology*, *46*(3), 233-251.
- Wilke, M., Hauser, T. K., Krägeloh-Mann, I., & Lidzba, K. (2014). Specific impairment of functional connectivity between language regions in former early preterms. *Human brain mapping*, *35*(7), 3372-3384.
- Wilson, S. L., & Craddock, M. M. (2004). Accounting for prematurity in developmental assessment and the use of age-adjusted scores. *Journal of Pediatric Psychology*, *29*(8), 641-649.
- Wolke, D., & Meyer, R. (1999). Cognitive status, language attainment, and prereading skills of 6-year-old very preterm children and their peers: the Bavarian Longitudinal Study. *Developmental medicine and child neurology*, *41*(2), 94-109.
- Wolke, D., Samara, M., Bracewell, M., Marlow, N., & EPICure Study Group. (2008). Specific language difficulties and school achievement in children born at 25 weeks of gestation or less. *The Journal of pediatrics*, *152*(2), 256-262.
- Woodward, L. J., Clark, C. A., Bora, S., & Inder, T. E. (2012). Neonatal white matter abnormalities an important predictor of neurocognitive outcome for very preterm children. *PLoS one*, *7*(12), e51879.

- Woodward, L. J., Moor, S., Hood, K. M., Champion, P. R., Foster-Cohen, S., Inder, T. E., & Austin, N. C. (2009). Very preterm children show impairments across multiple neurodevelopmental domains by age 4 years. *Archives of Disease in Childhood-Fetal and Neonatal Edition*, *94*(5), 339-344.
- World Health Organization (2012). *Born Too Soon: The Global Action Report in Preterm Birth*. Geneva.
- Yeung, H. H., & Nazzi, T. (2014). Object labeling influences infant phonetic learning and generalization. *Cognition*, *132*(2), 151-163.
- Yeung, H. H., & Werker, J. F. (2009). Learning words' sounds before learning how words sound: 9-month-olds use distinct objects as cues to categorize speech information. *Cognition*, *113*(2), 234-243.
- Young, G. S., Merin, N., Rogers, S. J., & Ozonoff, S. (2009). Gaze behavior and affect at 6 months: predicting clinical outcomes and language development in typically developing infants and infants at risk for autism. *Developmental science*, *12*(5), 798-814.
- Zhang, Q., Li, H., Zheng, A., Dong, X., & Tu, W. (2017). Evaluation of auditory perception development in neonates by event-related potential technique. *Brain and Development*.

APPENDICES

Appendix 1. Passages used in the familiarization phase in Experiments 1, 2 and 5 (from Nishibayashi et al., 2015).

/di/ [a saying] passage

Ce dit énoncé est bien formulé. J'aime quand il narre plusieurs dits imagés. Les dits annonceurs du mage sont à craindre. Elles ne relatent que quatre dits mensongers. Leurs dits ne doivent pas être entendus. J'ai appris quelques dits sur lui. Quatre dits sont prononcés par la femme. L'homme vocifère de nombreux dits contre lui.

/po/ [pot] passage

Trois pots bleus sont bien suffisants. Je mets quelques pivoines dans ce pot vert. Quelques pots en grès sont en vente. J'aimerais trouver quatre pots dans le jardin. Mes pots rouges en terre sont cassés. Il recycle ses pots contenant certains cornichons. Vos pots de yaourt se recyclent. Au marché cinq pots d'olive sont offerts.

/te/ [tea] passage

Le thé est une boisson savoureuse. Le matin je bois du thé au lait. Boire deux thés me réveille plus facilement. Je ne consomme que certains thés anglais. Certains thés sentent vraiment très bon. Ma fille aime sucrer son thé vert. Certains thés ne se trouvent qu'au marché. Tu n'achètes que ton thé en boîte.

/gu/ [taste] passage

Le goût de ces cerises m'enchanté. La fille n'aime pas le goût sucré. Ces goûts exquis et savoureux me plaisent. L'enfant se régale au goût de la crème. Mon goût préféré est celui de la menthe. L'alimentation varie selon les goûts de chacun. Nos goûts favoris sont le citron et le café. Au fur et à mesure nos goûts évoluent.

Appendix 2. Passages used in the familiarization phase in Experiment 3 (from Nishibayashi et al., 2015).

/di/ passage

Le dîner mondain m'ennuie horriblement. Leurs caddies contiennent beaucoup de denrées. Il lui a écrit un dizain romantique. Il vient d'arrêter cinq bandits dangereux. Tes deux divans rouges sont très confortables. Votre taudis vient d'être découvert. L'homme doit écouter deux ditos moralisants. J'aime manger ces deux radis salés.

/gu/ passage

Le goulot de la bouteille est brisé. Notre dégoût de la viande est surmonté. Il prépare un goujon citronné. Elle déguste ce bon ragoût cuisiné. Quelques gourous les influencent dangereusement. Les cagous ont des plumes argentées. Vous découpez des tranches de gouda salé. Vous trouvez parfois que son bagou dérange.

/po/ passage

Vos poneys broutent dans le pré. Quelques capots rouges sont froissés. Les filles raffolent de potins crapuleux. Les meubles sont rangés dans un dépôt scellé. Ton pommeau de douche est cassé. Notre topo a convaincu l'assemblée. J'ai rempli notre pochon de cerises. J'ai besoin de plus de repos en hiver.

/te/ passage

Trop de télé abrutit les enfants. J'habite près des cités des arts. J'ai marché sur un tesson de bouteille. J'ai acheté trois pâtés en croute. Quelques têtus sont dans cette classe. Le synthé lui sera offert à Noël. Les veaux boivent aux tétons de leur mère. Il existe quatre comtés dans la région.

Appendix 3. Passages used in the familiarization phase in Experiment 4 (from Nishibayashi & Nazzi, 2016).

/kɔl/ passage

Le col est obligatoire dans cet institut. Ce col n'est pas fermé à une heure pareille. Les cols pourront être repassés avec ça. Vous serez impeccables avec ces cols blancs. A navale les officiers ont des cols marins. Etonnamment nous abandonnons certains cols rouges

/sik/ passage

Les sikhs sont en rang devant le temple hindou. Le sikh ne doit pas se couper les cheveux. Des sikhs attendent en priant la venue de Dieu. Je n'ai jamais vu autant de sikh ici. Ce pays accueille de nombreux sikhs gris. En ces jours de prospérité plusieurs sikhs chantent

/kur/ passage

La cour d'honneur est ouverte au public. Un cours de math sera donné en amphithéâtre. Les cours boursiers n'en font qu'à leur tête aujourd'hui. Demain je vais suivre un premier cours d'arabe. Tu déploieras tous tes savoirs pour ce cours unique. Certains professeurs rendent leurs cours intéressants

/set/ passage

Les sets de tables ont été disposés. Le dernier set est remporté par le champion. Plusieurs sets en argent furent volés hier. Notre invité étranger offre des sets japonais. Beaucoup ont entendu la rumeur du set doré. Autrefois ces familles avaient un set complet

/kɔr/ passage

Le corps des marines est parvenu à la paix. Ce cor tant attendu sonne la fin des combats. Des cors en bronze produisent un son unique. Nous aimons le timbre grave des cors d'antan. Les musiciens de l'orchestre portent les cors dorés. Vous serez surpris d'entendre ces cors magnifiques

/sit/ passage

Un site internet ne peut être piraté. Le site archéologique a été piétiné. Quelques sites industriels français sont vides. De nos jours ils espèrent tous que les sites ouvrent. J'espère que d'ici un an des sites ferment. Dorénavant il faudra que ce site publie

/kul/ passage

Une coule est une robe à cape pour les moines. Cette coule grise trop longue ne m'appartient pas. La coule du frère bénédictin est brodée main. Je vais changer de ce pas votre coule usée. Les religieux souhaitent récupérer leurs coules bleues. Cette année le nouveau pape a une coule parée

/sek/ passage

Le sec se marie mieux avec le foie gras. Des secs sont à prévoir la semaine prochaine. Certains secs ne peuvent se marier à la viande. Un relief sous-marin peu profond est un sec bleu. Dans le désert égyptien tu peux voir ces secs arides. L'agence ne peut prévoir que quelques secs annuels

/rys/ passage

Les russes boivent de la vodka dès le matin. Un russe est venu me voir à l'ambassade. Des russes ont été aperçus près de la rivière. L'Europe s'est bâtie grâce aux russes du nord. L'agence spatiale accueille des astronautes russes préparés. Cette ville subit une influence russe importante

/bag/ passage

La bague du marié est trop grande pour son doigt. Ces bagues dorées valent au moins une maison. Des bagues sont proposées après la cérémonie. Le médecin lui a proposé les bagues dentaires. Les époux se sont échangés certaines bagues jolies. Je l'ai accompagnée pour choisir sa bague carrée

/ruz/ passage

La ville de Rouze est une commune française. La Rouze d'antan était grande, peuplée et connue. Cette Rouze dépérit au fil des années. Depuis son départ je n'ai vu qu'une Rouze pâle. Maintenant les guides préfèrent aller à Rouze en bus. Une navette relie la gare de certains Rouzes urbains

/bek/ passage

Le bec de cette chouette est drôlement amoché. Un bec jaune distingue la corneille du corbeau. Ce bec benzène est utilisé par quelqu'un d'autre. Les ornithologues aiment observer les becs d'oiseau. Plusieurs spécialistes détaillent ces becs bleus. Toutes ces espèces présentent des becs cornus

/ryz/ passage

Cette ruse infantile est vieille comme le monde. La ruse est la meilleure arme dans ce royaume. Une ruse trompe les ennemis de la couronne. Dans le passé j'ai été victime de ruses parfaites. Les enfants terribles font de belles ruses méchantes. De tout temps les plus courtes ruses sont les meilleures

/bak/ passage

Le bac était très simple pour les lycéens. Ces bacs à linge sont en plastique recyclable. Des bacs ont été mis à disposition des filles. Malgré la chaleur de ce mois les bacs tiennent. Les jeunes hommes nettoient quelques bacs de cuisine. Il préfère corriger un bac scientifique

/rus/ passage

Cette rousse est bien connue des services secrets. La rousse chante avec son groupe musical. Les rousses étaient considérées comme des sorcières. Il aimerait photographier des rousses belles. Nous voudrions consulter une rousse jalouse. Preuve est faite qu'il existe certaines rousses joviales

/beg/ passage

Ce bègue parle avec éloquence en public. Un bègue peut exercer le métier de comédien. Quelques bègues sont présents durant le cours. L'orthophoniste rencontre des bègues sympathiques. Il faut souvent encourager ces bègues timides. C'est bien de travailler avec les bègues volontaires

Appendix 4. Transcriptions of stimuli used in Experiment 6.

French Monologue:

« Alors le premier petit cochon décide de se construire une maison en paille. Il trouve de la paille au bord de la route et il construit vite vite sa maison, il rentre dedans, et il est très heureux. Le deuxième petit cochon, décide de se construire une maison en bois. Il trouve du bois au bord de la route, il se construit une maison et il est très heureux. Le troisième petit cochon décide de se construire une maison en briques. Il trouve des briques au bord de la route. Il met très longtemps à construire une maison en brique mais à la fin quand il a fini, il rentre dedans et il est très heureux. Un jour, les trois petits cochons jouent dehors et ils voient approcher le loup. Vite vite, les trois petits cochons courent et rentrent dans leurs maisons. Le loup s'approche de la première maison, la maison en paille. » (153 words)

English Monologue:

“The first little pig found some straw by the road and decided to build a straw house. So quickly, as fast as he could, he built himself a straw house. The second little pig found some wood next to the road and decided to build himself a wood house. So he very very quickly made himself a beautiful wooden house. The third little pig decided to build a big strong house made out of bricks. So he found some bricks and he took him a long time but at the end he made himself a beautiful brick house and he was very happy. One day the three little pigs were playing outside when a wolf came along. So they quickly ran into the houses and closed the doors. The wolf came up to the first house, the house made of straw, and said: Little (...)” (143 words)

Appendix 5. Babbling questionnaire used in Experiment 6.

Questionnaire sur le babillage

Est-ce que votre enfant fait des bruits comme :

| | <u>Des voyelles</u> | pas encore | oui |
|----|--|-----------------------|------------|
| a | <i>[par exemple, "aaaaa" comme dans le mot "sa"]</i> | | |
| i | <i>[comme dans le mot "si"]</i> | | |
| é | <i>[comme dans le mot "ces"]</i> | | |
| e | <i>[comme dans le mot "ceux"]</i> | | |
| o | <i>[comme dans le mot "sot"]</i> | | |
| ou | <i>[comme dans le mot "dessous"]</i> | | |
| u | <i>[comme dans le mot "dessus"]</i> | | |

| | <u>Des syllables</u> | pas encore | oui |
|---|--|-----------------------|------------|
| Une suite de syllables identiques: | | | |
| | <i>avec une "semi-voyelle"</i> exemples: "yayaya" ou "wawawa", etc. | | |
| | <i>avec une "propre" consonne</i> exemples: "bababa" ou "dedede", etc. | | |
| Une suite de syllables différentes : | | | |
| | <i>avec des consonnes différentes</i> par exemple: "badaga" ou "gamaya" | | |
| | <i>avec des consonnes <u>et</u> des voyelles différentes</i> par exemple: "badigu" ou "adoyi" | | |

Appendix 6. iMaps of fixations across the duration of the experiment for the group of 6-month-old fullterms (6FT), 8-month-old preterms (8PT) and 8-month-old fullterms (8FT) in the native (French) and non-native (English) language.

